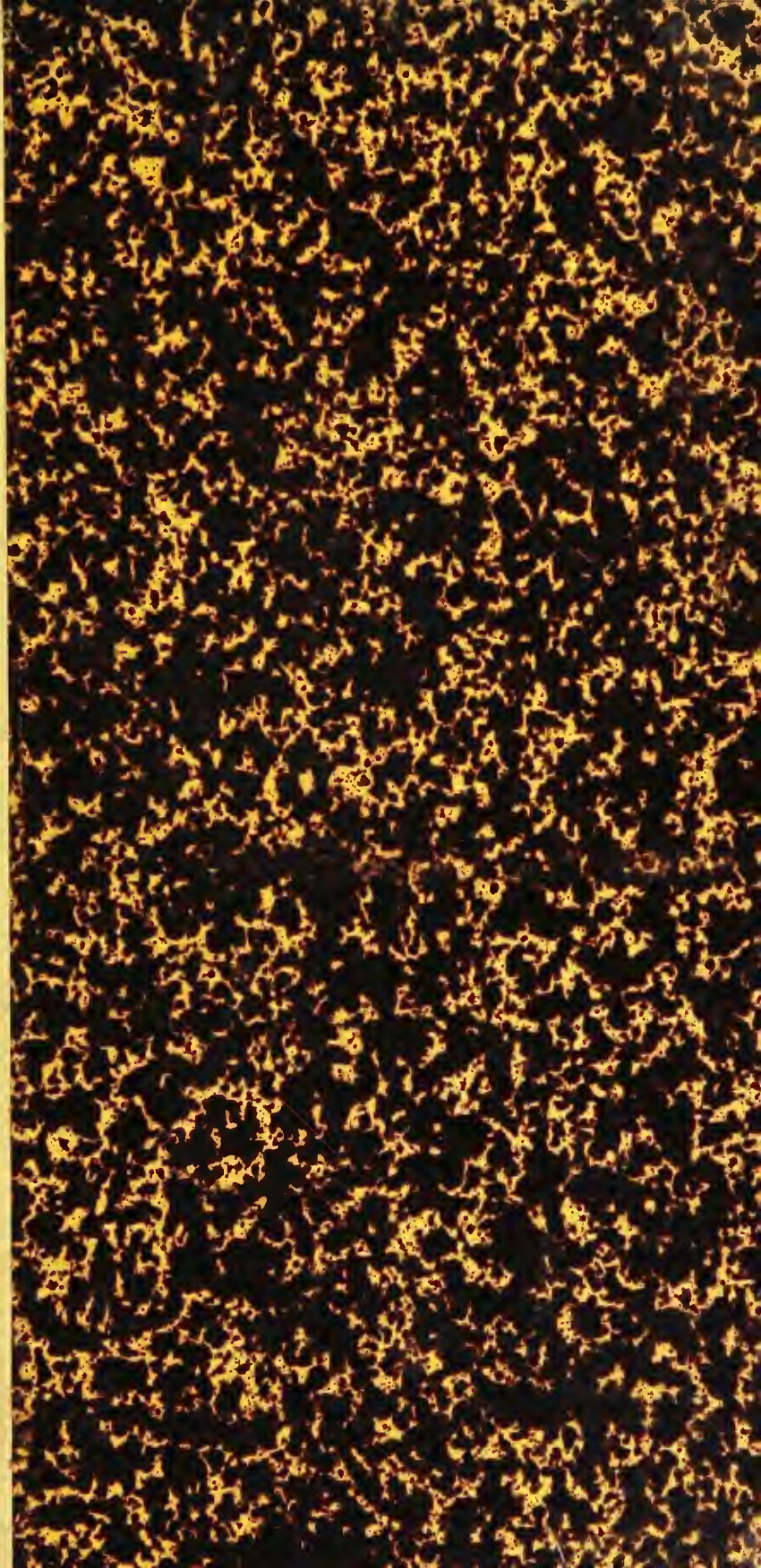

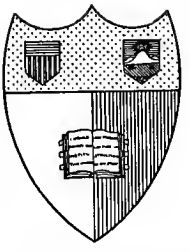

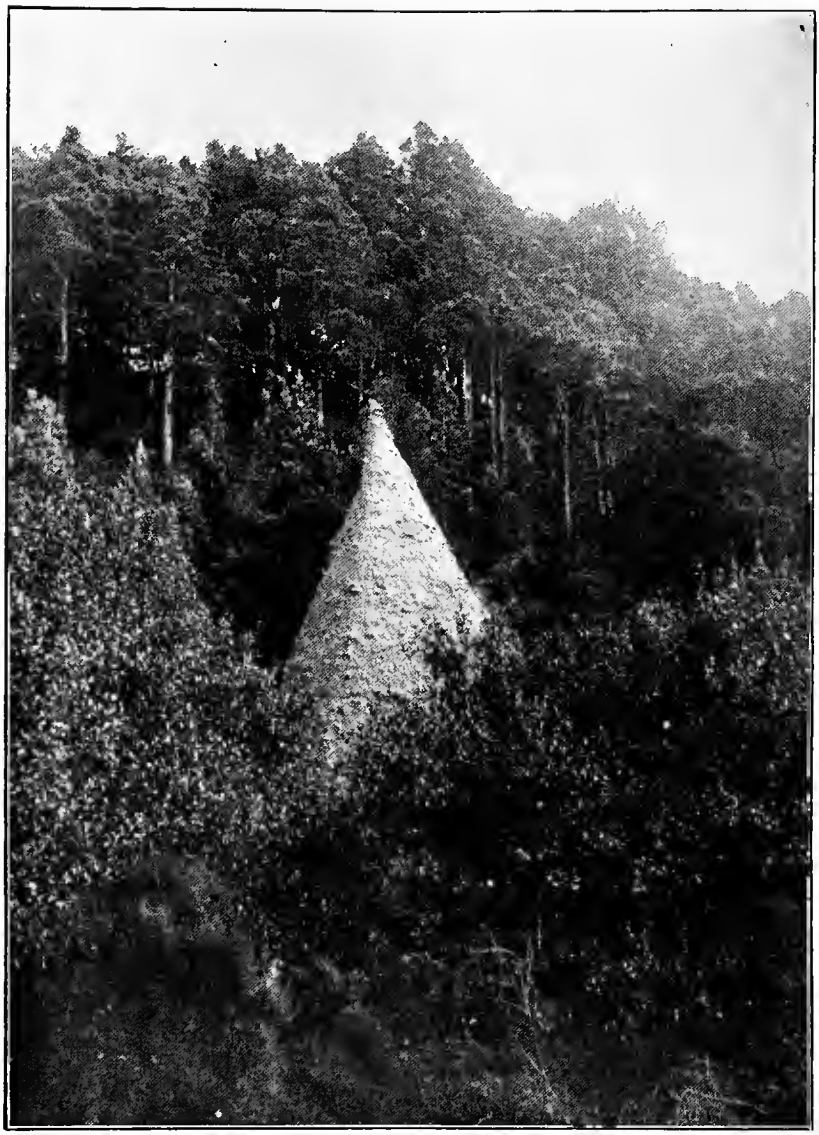

PLATE I.

Earth Pillar—Allt Dearg, Fochabers.

MEMOIRS OF THE GEOLOGICAL SURVEY.

# SCOTLAND.

# THE GEOLOGY OF LOWER STRATHSPEY

(Explanation of Sheet 85.)

BY

L. W. HINXMAN, B.A., F.R.S.E.

AND

J. S. GRANT WILSON

WITH

Petrological Chapter and Notes by

J. S. FLETT, M.A., M.B., C.M., D.Sc.

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# PREFACE

THIS memoir describes the geology of the area included in Sheet 85 of the one-inch map of Scotland, which embraces the district of Lower Strathspey and adjacent tracts in the counties of Elgin, Banff, and Aberdeen. The ground was originally mapped by Mr. Hinxman, Mr. J. S. Grant Wilson, and Mr. Linn, and at a subsequent date the area occupied by the Banffshire series of the crystalline schists, in the south-east part of the Sheet, was re-examined by Mr. Wilson.

Dr. Flett has contributed a chapter (Chapter VII.) on the petrography of the plutonic masses and certain types of the metamorphic rocks, and on the contact metamorphism produced by the igneous intrusions. While preparing his materials he visited the area for the purpose of studying some of the phenomena in the field.

Special thanks are due to Dr. Traquair, F.R.S., for his report on the fossil fishes of the Old Red Sandstone of Scotland, and the list of the fishes found at Scaat Craig; to Mr. R. Kidston, F.R.S., for his notes on the fossil plants of the Old Red Sandstone of Scotland; and to Mr. Taylor, Lhanbryde, near Elgin, who has supplied a list of the fishes found by him at various localities in that formation in the Sheet.

The three Plates have been prepared from photographs taken by Mr. Lunn, of the Geological Survey, and the Bibliography given in the Appendix has been compiled by Mr. Hinxman.

The manuscript has been edited by Mr. Horne.

J. J. H. TEALL,
*Director.*

GEOLOGICAL SURVEY OFFICE,
LONDON, *16th January, 1902.*

# CONTENTS.

# LIST OF ILLUSTRATIONS.

# EXPLANATION OF SHEET 85.

## CHAPTER I.

Area Embraced in the Map.—The district represented in Sheet 85 of the Geological Survey Map of Scotland includes an area of 432 square miles, almost equally divided between the counties of Elgin and Banff, which lie on either side of the river Spey. Charleston-of-Aberlour may be regarded as the centre of the map, which extends in the north from Newmill westwards to the village of Rafford, and in the south from the Black Hill near the Lower Cabrach to Dalliefure on the Spey.

Form of the Ground.—The highest ground in the area is found in the south and south-west, whence the surface of the country falls northwards to the shores of the Moray Firth.

The dominant feature of the district is the granite mass of Ben Rinnes and the Convals. The long ridge of Ben Rinnes, crowned with rock-masses locally known as "scurrans" (*Gaelic* sgoran), rises gradually to a height of 2755 feet at its eastern extremity, and from its isolated position forms a well-known landmark over a vast extent of country. Another tract of high ground, with summits ranging from 1500 to over 2000 feet, borders the area in the south, and extends westwards from the hills of the Glen Fiddich Forest to the northern spurs of the Cromdale range which divides the Avon Valley from Strathspey. A third hilly region of lower elevation forms the watershed between the Spey and Lossie, and extends far to the north-east in a wide expanse of rolling moorland with a mean elevation of over 1000 feet, that falls gradually northwards to the cultivated lowlands of the Laigh of Moray. Separated from this high plateau by the valleys of the Spey and Lossie, are such isolated eminences as the quartzite peak of Ben Aigan, above Craigellachie —1544 feet; and the long ridges of Eildon Hill and the Hill of the Wangie, which rise with steep faces to the south above the valleys of the Lossie and the Black Burn. The country between the Deveron and Isla and to the north and north-west of Keith is undulating, and broken into low hills and valleys. The smooth rounded hilltops are clothed with wood or heather, while the slopes and valley-bottoms are entirely under cultivation.

River Systems.—The chief drainage-system is that of the Spey and its tributaries, fully two-thirds of the area being included

within the basin of that river, which crosses the centre of the sheet from south-west to north. On the right bank it receives at Ballindalloch its most important tributary, the Avon, a small portion only of whose course falls within this map, and lower down it is joined by the Fiddich at Craigellachie. On the left bank there are many smaller affluents, such as the Tulchan Burn, the Allt Gheallaidh, and other streams flowing off the southern slopes of the Elginshire moorlands. The north-west portion of the area is drained by the river Lossie, the eastern borders by the Isla and the Deveron.

Lakes.—Loch Dallas, Loch Noir, and other smaller pools, all of which occupy shallow hollows in the drift-covered moorlands round the head waters of the Lossie, are the only natural pieces of water in the map. Many of the depressions in the sheet of gravel that extends to the north and south of Rafford were also at one time occupied by small shallow lochans. These have now disappeared, either through drainage operations or by natural silting up and vegetable growth filling their beds. L. W. H.

## CHAPTER II.

### *Geological Features and Surface Relief.*

An examination of the map will at once show the influence of the geological structure on the features of the country. The hills and higher ridges in the south and south-east have been determined by the outcrop of the harder quartzite masses, and follow the direction of their strike; while the valleys have been excavated along the bands of softer slates and phyllites of the Banffshire series.

The central granite protrusion gives rise at once to the most prominent features and to the highest mountain in the district; the lofty peak of Ben Rinnes, the rounded forms of the two Convals, and the ridge of the Hunt Hill on the north side of the Spey being due to the unequal wasting of this mass of igneous rock. The high-level moorland plateau between the Spey and the Lossie is formed from the quartzo-micaceous schist and flagstone series, and owes its smooth contours and more or less featureless character to the comparative homogeneity and equal weathering of these rocks. The chain of hills that runs northwards from Craig an Tarmachain on the south edge of the sheet to Cragganmore is a higher part of this plateau, isolated by the deep valleys of the Avon and the Spey. Ben Aigan is another isolated eminence formed by an outlying mass of hard quartzite surrounded by softer rocks, while to the incoherent conglomerates and soft sandstones along the northern border are due the fertile lowlands that descend to the seaboard of Moray.

The only prominent feature due to faulting is the straight trench-like hollow that extends from Dufftown past Rothes nearly to the edge of the sheet. It coincides with a dislocation running N.N.W. and S.S.E. with a downthrow to the E., and has defined the lower valley of the Fiddich, the course of the Spey between Craigellachie and Rothes, and the deep glen of Rothes through which now passes the railway to Elgin.

The elements of surface-relief due to glacial action are chiefly those of accumulation rather than of erosion. The original features of the surface are to a large extent softened and modified by the drift deposits which lie thickly in the valleys, swathe the hillsides, and sweep over the cols, leaving only the higher hilltops bare of superficial covering. Erosive action may, on the other hand, be traced in the rocky faces that are occasionally found low down on the sides of the wider river valleys, as at the Craigs of Callander, at Tulchan, and at Culfoichmore, in Strathspey. These may be

ascribed to the action of the later valley glaciers, which have swept out the deposits of an earlier ice-sheet from the bottom of the valley, leaving bare the projecting parts of the lower hill slopes. It is noticeable that these rock-surfaces are most frequent where the hillsides are steep and there is a certain amount of constriction in the valley—that is at the points where the ice would exert the greatest abrading force.

Many of the smaller tributary valleys have been completely filled with glacial deposits, through which the present stream is now cutting a new channel. An excellent example of such a drift-filled pre-glacial valley is seen along the Allt Arder, north of Ballindalloch (*see* Chap. IX.).

The drainage system of a country composed of intensely plicated metamorphic rocks such as occupy the western portion of this area may be expected to be a complex one, in which the laws which govern the flow of streams through comparatively homogeneous and undisturbed strata will be considerably modified. We therefore find that the valley of the Upper Spey is to a large extent inconsequent, that is, independent of the strike and inclination of the rocks through which it passes. The lower course of the Avon is, on the other hand, for a long distance approximately parallel to the strike of the rocks, and has probably been determined by the outcrop of a band of felspathic flagstones softer in nature than the more siliceous strata that form the hills on either side of the river valley.

Further anomalies found in the east and south-east parts of the district are due to the fact that the present drainage system is in part a superimposed one, and caused by an uplift of strata of Old Red Sandstone age. These rocks may at one time have covered nearly the whole area, but have since been removed by denudation except along the northern margin of the sheet.

The position of certain outlying fragments of this once widespread covering affords direct evidence that many of the river valleys are of pre-Old-Red-Sandstone age, and were originally determined by the nature and distribution of the various members of the metamorphic series. Patches of sandstone and conglomerate occur at several points along the courses of the river Lossie and the Black Burn, between whose parallel valleys the ridge of schistose rocks that forms the Hill of the Wangie rises to a height of 400-600 feet above the present valley-level. Another striking instance is found on the headwaters of the river Isla, near the farm of Upper Towie, about four miles south-west of Keith. The stream here flows for some distance over a floor of conglomerate which fills up the bottom of a deep valley excavated in the black schist. The small patch of conglomerate upon which rest the piers of the railway viaduct that crosses the Fiddich near Dufftown is again the last relic of a mass of Old Red Sandstone that at one time filled the valley of that river. Similar evidence as to the age of the valley of the Tervie Burn is afforded by the small area of conglomerate seen along the stream side at Craighead, close to the southern margin of the map. This valley has also been carved

out of the softer rocks of the Banffshire series between two ridges of quartzite, of which that on the north side rises to a height of 1000 feet above the bottom of the valley.

The Deveron, Fiddich, Dullan Water, and Isla, that drain the area occupied by the Banffshire series, were thus at one time consequent streams as regards this covering of Old Red Sandstone that dipped towards the north. They now follow the strike of the underlying schists, and are thus subsequent with respect to the rocks that form the present surface of the country. Their present north-east course is probably a modification of the superinduced northerly course, and was produced when the original features due to unequal hardness of the metamorphic rocks reasserted themselves as the overlying strata were removed.

To this cause may be attributed the remarkable deviation in the course of the Fiddich at Coldhome, where the river bends suddenly round and flows westwards to Dufftown, making an angle of less than 60° with its track above the bend.

The ridge between Carron Hill and the Tips of Corsemaul now forms the watershed between the Fiddich and the Isla, and rises nearly 400 feet above the valley of the former stream. But at the time when ridge and valley were alike concealed beneath the covering of Old Red Sandstone strata, the upper waters of the Fiddich would naturally flow northward across the present watershed into the valley of the Isla. In the process of time the sandstones covering the ridge of metamorphic rocks were gradually removed by denudation, and the stream, finding it easier to erode the softer rocks that still filled up the Dufftown valley than to cut through the ridge of schist and quartzite, turned to the west, thus robbing the Isla of its headwaters and swelling the volume of a smaller stream that must already have been cutting back out of the head of the fault-determined valley below Dufftown.

A similar course of events seems to have determined the courses of the river Lossie and the Black Burn in the north-west portion of this area.

Prior to the removal of the general covering of sandstone from this region the Lossie flowed seaward as a consequent stream, with the same northerly trend that it still retains in the upper part of its course above Dallas. It was joined by the Black Burn on the west side of the Hill of Mulundy, and the combined streams, passing northwards through the well-marked hollow through which now runs the road to Rafford, fell into the river Findhorn somewhere near the present site of Forres. As the sandstone covering was gradually removed by the wasting process, the earlier topographical features would again come into play; and the Lossie, turned aside by the ridge of metamorphic rocks that runs eastwards from the Hill of Mulundy, eroded the softer strata that still occupied the hollow and returned to the ancient river valley below Dallas. The watershed between Rafford and Briach Mill is only about twenty feet above the present level of the Black Burn at the latter locality. It is thus probable that this stream retained its northerly course to the Findhorn to a considerably later period. Finally

however, the influence of the original surface features, coupled as in the case of the Lossie with the cutting-back of a stream in the valley to the east, produced the present deviation of the Black Burn eastwards under the Eildon Hill.

The present channel of the Lower Spey, apart from the valley through which it flows, is largely post-glacial. Over the greater part of its course through this sheet, and especially between Ballindalloch and Carron, it is flowing over rock and still deepening its bed, while the mass of fluvial and glacial deposits that still remains in the principal and tributary valleys shows how deeply it has trenched the waste-filled basin since glacial times. The swiftness of its lower course, which is abnormal in comparison with the gradient of its middle section, is probably the effect of an uplift along an axis that crosses the river considerably further up the valley, and is of later date than the erosion of the higher portions of its course.

The Spey may thus be regarded as a compound river, made up of two sections of different age, and at unequal stages of erosion; while the portion which falls within the region under description has been rejuvenated by uplift, and, like many other streams in the area, affords an example of superinduced drainage.

A well-marked constriction of the Spey Valley occurs at Aikenway Castle, 1½ miles N.N.E. of Rothes. At this point the quartzite of Ben Aigan at one time formed a rock-barrier which dammed back the waters of the Spey over what is now the fertile Haugh of Rothes, and was possibly high enough to divert the course of the river north-westwards through the Glen of Rothes. Indications of this former course of the Spey are found in the high-level terraces that flank that glen, and can be traced southwards into the river terraces between Rothes and Knockando (*see* Chap. IX.). L. W. H.

*Geological Structure in Relation to Population and Economics.*

A close connection exists between the geological structure and the distribution of the population of the country represented in this map. This relation between structure and population only holds good, however, for ground below 1000 feet above sea level, for at higher elevations grain and green crops cannot be profitably cultivated in this part of Scotland. Outside the burghs of Keith, Dufftown, Rothes, and the villages of Aberlour, Newmill, Archiestown, and Dallas, which are more or less engaged in small local industries, the remaining portion of the sheet is either agricultural, pastoral, or moorland.

The first factor which has determined the distribution of the agricultural population appears to be the geographical position of the various alluvial haughs, terraces, and fluvio-glacial gravels which are distributed along the valleys of the Black Burn, the rivers Lossie, Spey, Avon, Dullan Water, Fiddich, Isla, Deveron, and their various tributaries.

It was on these terraces and lower valley slopes that the

agricultural population first settled in farms and crofts, while the further extension of agriculture and population higher up the hill slopes and across the areas which separated one valley from another was chiefly determined by the nature of the intervening rock zones. There is also an intimate connection between the size of the farms and the extent of the alluvial deposits at any one point. From Dandaleith to Dipple the river Spey has deposited the largest haughs and terraces in this sheet, and on these are situated the largest farms in the map.

The decomposition of the granulitic flagstones and schistose grits produces a poor, damp soil, which is neither adapted for arable nor pastoral purposes. These grits and flagstones are generally covered by turf-peat and heather, while deep peat mosses occupy the hollows. We thus find that on the west side of the Spey and on either side of the river Avon the ground over which this series extends is chiefly utilised as grouse moors with a few scattered grazings, while the population of this portion of the country is almost entirely confined to the alluvial haughs and terraces which intersect it.

The Middle Old Red Sandstone series, which extends from the Gallows Hill to the river Lossie, is entirely composed of a coarse conglomerate with a thin covering of gravelly soil. As this ground is very suitable for the growing of timber, a large portion of this area has been planted, and in consequence there is a very scattered population. On the Teindland and around Thomshill the conglomerate is covered with a considerable thickness of sharp gravelly drift. This deposit is largely derived from the denudation of the Upper Old Red and Triassic Sandstones of the "Laigh of Moray" and was laid down over this part of the country by the Moray Firth ice sheet. The whole of this area along with the small portion of Upper Old Red Sandstone at Longmorn is well cultivated and maintains a full agricultural population.

From the east side of the Spey to the margin of the sheet those areas of the map which are occupied by the phyllites, black-schist, and limestone, are generally well cultivated up to 1000 feet. Surface drift derived from these rocks affords a clayey soil, the lower part of which is generally a stiff till, and where this is mixed with the peat in the valley bottoms a clayey loam is produced up to 1000 feet. An agricultural population is pretty evenly distributed in crofts and small to medium sized farms all over that portion of the map occupied by these three members of the Banffshire series, with the exception of that part which is included within the Glen Fiddich deer forest. Above the limit of cultivation over these three zones the ground is either pastoral or else planted with timber, with a very sparse population.

From Ben Aigan to the Black Hill of Corinacy many of the hill-tops and ridges are occupied by the Banffshire quartzite, a hard siliceous rock which does not readily produce soil. Many of these hills carry no soil and are frequently covered with their own debris overlaid with turf-peat and heather. When soil covers these quartzite areas it is similar to that produced by the "Cromdale

Hills series," and as it is poorly adapted for cultivation there is almost no population where quartzite forms the rock of the country. An exception to this absence of population over a quartzite area is found at the foot of Glen Markie and around the Burn of Edinglassie. These two small valleys have a thick covering of drift chiefly derived from the phyllites and black schists which are in place to the W.S.W. of them. This is another instance within the sheet where the character of the glacial deposits and not the solid rock beneath has influenced the distribution of the population. J. S. G. W.

## CHAPTER III.

### *Formations and Groups of Rock.*

#### AQUEOUS.

| | | | SIGN ON MAPS. |
|---|---|---|---|
| Recent and Post-Tertiary. | | Peat | —•— |
| | | River and Lake Alluvium | ⌒⌒ |
| Glacial Drift. | | Moraines. | |
| | | Erratic Blocks. | |
| | | Sands and Gravels. | |
| | | Brick Clays. | |
| | | Boulder Clay. | |
| | | Striated Rock Surfaces. | |
| Old Red Sandstone. | Upper. | Sandstones | $c^3$ |
| | Middle or Orcadian. | Conglomerate and Sandstones | $c^1$ |

#### METAMORPHIC.

| | | |
|---|---|---|
| Banffshire Series. | Quartzite | 𝔵 |
| | Schistose Grit | 𝔷 |
| | Limestone | λ |
| | Dark Slates and Schists ("Black Schist") | $\mathfrak{l}^{i}$ |
| | Clay Slates and Phyllites | 𝔩 |
| Granulitic Schists of Central Highlands. | Mica Schist | 𝔤 |
| | Granulitic quartzite, Quartzo-micaceous Schists, and Flagstones | $\mathfrak{x}^{m}$ |
| | Undifferentiated Schists and Gneisses | 𝔪 |

#### IGNEOUS.

| | | | |
|---|---|---|---|
| Contemporaneous—Andesite of Old Red Sandstone Age | | | $Poc^1$ |
| Intrusive. | Post-foliation. | Lamprophyre | $S^M$ |
| | | Diorite | D |
| | | Granite | G |
| | Pre-foliation. | Serpentine | |
| | | Gabbro | U |
| | | Epidiorite and Hornblende-Schist | $B^G$ |
| | | Foliated Granite or Augen-Gneiss | $G^{\phi}$ |

In the published map the symbol $c^1$ has been used for the Middle or Orcadian Division. In the edition which will be subsequently issued $c^2$ will be used.

*General Geological Structure of the Area.*

The ground east of the river Spey is chiefly occupied by the rocks of the Banffshire series, the various members of which are arranged in a succession of roughly parallel bands across the south-eastern portion of the map between Glen Tervie, south of Ben Rinnes, and Keith. These quartzites, schists, and limestones represent a portion of the belt of more or less altered sedimentary rocks with associated igneous intrusions which extends almost continuously across Scotland from the south-west of Argyllshire to the Moray Firth. They are particularly well developed in the adjoining sheet to the south (75), and have been described in the explanation accompanying that sheet.

The granulitic schistose rocks of the Central Highland or Moine schist type cover almost the entire western half of the map. The more siliceous portions of this group have been coloured yellow on the map, but are distinguished from the quartzites of the Banffshire series by the addition of the letter m to the index-symbol *x*.

The quartz schists and flagstones form the western slopes of Ben Rinnes, the Cromdale Hills, and the high ground that rises to the north-west of the Spey between Allt Arder and Delliefur; while the wide moorlands that stretch northwards from the watershed to the head waters of the Lossie are occupied by the undifferentiated schists and gneisses of this series. The separation of the various rock-types in this latter area is rendered difficult and indeed often impossible by the great extent and thickness of the peat and drift with which the hills are covered and the consequent absence of rock sections. For the same reason the line drawn on the map between these rocks and the more siliceous group in the south, is a very conjectural one.

A considerable area of conglomerate and sandstone occupies the ground on either side of the Spey north of Rothes. These sediments rest unconformably upon the schists, and are presumably of Orcadian or Middle Old Red Sandstone age. To the north of the Glen of Rothes and along the margin of the map these are in their turn covered unconformably by sandstones belonging to the Upper Old Red Sandstone period, while smaller patches of these latter rocks also occur at Dallas, Pluscarden, and Rafford.

The plutonic rocks are confined to the central and eastern portions of the area under description, and the almost entire absence of igneous masses in the Central Highland schists is a striking feature of the western half of this sheet. The earlier intrusions are represented by the basic and ultra-basic sills associated with the Banffshire series and intruded into those rocks prior to the movements that produced their present schistosity. To the same period may be assigned the foliated granites or augen-gneiss that pierce the schists in the neighbourhood of Keith.

Later than the schistosity is the large mass of unfoliated granite which disrupts the rocks on both sides of the Spey at Aberlour, and forms the mountain mass of Ben Rinnes and the Convals. A more

basic phase of this intrusion is probably represented by the diorite of Hill of Stob and Netherly on the Burn of Rothes.

A few lamprophyre dykes are found in the quartz schists of Ben Aigan, and a bed of contemporaneous porphyry or andesite occurs in the Old Red Sandstone of the Cabrach outlier, in the south-east corner of the map. L. W. H.

## CHAPTER IV.

### *Metamorphic Rocks.*

#### Quartzite.

On the east side of the river Spey the metamorphic rocks have been thrown into a series of isoclinal folds which have determined their arrangement over this area. It is more than probable there is only one zone of quartzite; the repetition of the rock in parallel bands and detached lenticular masses, whose longer axes lie north-east and south-west, being due to this system of folding. As already indicated, the quartzite, owing to its greater hardness, invariably forms the hills and ridges, while the lower slopes and valleys are carved out of the softer phyllites, black schists, and limestone. In this sheet there is no direct evidence that the quartzite rests unconformably on the other members of the Banffshire series. The indirect evidence is very strong, for a glance at the map shows that the main belt of quartzite which stretches from the Glen Fiddich forest to Invermarkie is at various points in contact with phyllite, black schist, and limestone. But it should be borne in mind that, throughout the area included in Sheet 85, the quartzite, phyllite, black schist, and limestone have been affected by a common system of folds. In character the rock varies from a very fine-grained homogeneous crystalline-granular rock to a hard massive granulitic quartzite. In colour it varies from grey white to a dirty yellow, and the finer-grained varieties when freshly broken have a pinkish colour. The quartzite hilltops of this portion of Banffshire are often covered with its debris, which weathers with a snow-white colour. Over the greater portion of the northern half of the area this rock is felspathic and granulitised, and often passes into a quartzo-felspathic schist with white mica developed along the divisional planes, while towards the south-east the original clastic grains can still be recognised, and in several localities bands of pebbly grit prove the sedimentary origin of the rock.

In proceeding to describe the various areas of quartzite from north-west to south-east, the first in order is that which extends from near Craigellachie to the north of the Burn of Mulben and forms the hills of Ben Aigan (1544 feet), and Knock More (1167 feet).

The quartzite throughout this area is very uniform in character, massive and granulitic, with the bedding planes well defined. Numerous dips have been observed in the streams which flow down the western slopes of Ben Aigan, and these indicate a general

inclination to north-east and south-west. For about two miles along the river Spey north and south of Boat of Bridge, a hard, massive, purple quartzite is exposed. In the Burn of Mulben and north to the boundary of the Old Red Sandstone this rock is very much shattered, and the subangular brecciated portions have all been re-cemented together by a siliceous base into a homogeneous rock with occasional drusy cavities in which occur crystals of quartz or barytes. The purple colour of the rock extends as far south as the Woods of Knockmore, and is due to staining by Old Red Sandstone. In the Burn of Mulben and within a short distance of the eastern limit of this area bands of quartzite and phyllite are folded together.

At Sheriffhaugh this rock loses its brecciated character, and the Allt Daley which flows into the river Spey at this point affords an almost continuous rock section to within a short distance of the top of Ben Aigan. In the lower portion of this section thin bands of quartzite inclined to E. 12 S. at angles varying from 10°—15° alternate with quartz schist and flagstones. Higher up, the dip is inclined more to the south, the quartzite becomes more massive, and the thicker and harder bands give rise to a series of cascades. Towards the top of the hill the rock is occasionally brecciated, and at the head of the section bands of quartzite are folded with the mica-schist which occupies the ground to the east.

The tops of Knock More and Ben Aigan are covered with angular debris of pink, grey, and yellow quartzite with very fine dendritic markings, weathering white. On the banks of the river Spey at Aikenway and below Arndilly House the rock is very much shattered, and has been converted into a breccia with large and small subangular fragments cemented together in a siliceous matrix and stained purple by the recently removed Old Red Sandstone beds. The eastern boundary of this area is shown on the map by a comparatively straight line, but this is due to the want of exposures between the Glen of Mulben and Tanzie. At the latter point a massive quartzite with black-schist above passes in below the mica-schist to the east. The upper portion of the burn which flows past Arndilly House runs through a ravine with steep cliffs of white and pink quartzite.

To the south of Rothes and on the east side of the wood of Conerock there are several exposures of a very peculiar rock. It is a brecciated-looking complex of vein quartz and quartzite in a siliceous matrix stained irregularly in strings and patches with hæmatite. The "Cone Rock," at one time the site of an ancient fort, is situated in the wood half a mile to the west of Haughs, and is entirely composed of this brecciated rock. It is probably a fault breccia due to the line of dislocation described in Chapter II. It contains numerous drusy cavities of all sizes lined with crystals of quartz, and when cut and polished has a very beautiful appearance.

Between Dufftown and Herricks Moss, north of Keith, small isolated lenticular masses of quartzite occupy the tops of several of the hills. A narrow belt of white quartzite extends along

the north-east bank of the river Fiddich on both sides of Kininvie House, and in the branch burn at Hazelwood Cottage vertical beds of the same rock are seen alternating with black-schist and mica-schist. A considerable area of quartzite covers the Scaut Hill and extends to the north-east as far as the Lochend Wood. On the roadside opposite to Waulkmill the rock is much shattered by the fault which follows the valley of the river Fiddich between the Mains of Newton and Balvenie Castle. In a small stream to the north-east of Little Tulloch the highly inclined beds are finely conglomeratic. The nature of the debris on the top of this hill shows that the underlying rock is fine grained and in places not much altered.

The flat moor between the Knockan and Machatties Cairn is free from drift and covered by white quartzite debris and heather. North of the "Cairn," in the small burn which passes down to Broadrashes, bands of quartzite, black-schist, and phyllite, all inclined at high angles, are seen folded together. A glance at the map shows that in the north-eastern portion of this area the quartzite is thrown into five sharp folds. In Tauchers Wood there are several exposures of bands of pink quartzite with yellow spots, inclined to the south-east at angles varying from 30°—50°.

The rock which occupies the Moor of Auchanacie is a fine-grained light-brown foliated quartzite with ill-defined patches of brown staining. In many places it passes into a quartz-schist with white mica developed along the planes of foliation. A similar rock forms the small lenticular mass at Blackhill Wood to the south-west of Keith. In the north-east corner of this sheet a wedge-shaped area of quartzite stretches from Herricks Moss to within a short distance of Newmill. In the stream section to the south of the moss the rock is inclined to E. 25 S. at comparatively low angles and consists of hard, laminated, flaggy quartzite. The extension of this band to the south-west has been traced by means of numerous shallow quarries and rock knobs. The western slope of the Cairds Wood Hill south of Keith is occupied by a lenticular area of very hard massive quartzite traversed by numerous veins of quartz. At Drummuir Station the ground between the public road and the railway is covered by an oval shaped area of very hard yellowish quartzite surrounded by a belt of black-schist. At the back of the station this schist is seen passing in below the quartzite with a south-easterly dip.

South of Dufftown the ridge of high ground which separates the valleys of the Dullan Water and river Fiddich is also formed of quartzite. To the south-west of Pitglassie it is brecciated and granulitic, while crags of white quartzite rise to the south of Cairnmore. Between Carron and Bellyhack Hills, in the Parish of Botriphnie, no rock is seen in place, but the surface is thickly covered with angular quartzite debris.

The largest band of quartzite enters this sheet in the Glen Fiddich Forest to the south of the Hill of Glenroads and traverses the map in a north-easterly direction. This is the northern extension of the area which lies on the west side of Glen Suie* in the sheet to the

* Explanation of Sheet 75, p. 9.

south (75). Its outline is very irregular, and its breadth varies from 400 yards up to 3 miles. From the southern boundary of the map to Glen Fiddich lodge very little rock is seen in place, but its position is inferred from the quantity of quartzite debris which covers the hilltops. A glance at the map shows the folding of the quartzite in Glen Fiddich between Tor Elick and the Hill of Clais nan Earb, with the result that the same beds of phyllites and limestone are repeated on both sides of these two hills. From the lodge to below Smithstown, the river Fiddich exposes a good section consisting of grey, flaggy, massive quartzite with mica-schist partings inclined to the south-east at various angles. To the north-east of Laird's Seat grey phyllites pass in below this rock, and at Laggan, where the boundary line crosses the river, a cliff of soft decomposing quartzite is in close proximity to the black-schists. To the north of the Scalp Hill this belt of quartzite is thrown into a series of folds, and its boundary then turns to the south as far as Garbet Hill at the head of Glen Markie.

That the beds of quartzite are often repeated by folding to the east of Glen Fiddich is evident from the fact that between Cairn Crome and Ben Main there are three small areas of phyllite and limestone entirely surrounded by quartzite. Between the Meikle Balloch Hill and Burntreble the strike of the beds changes from its normal direction to north and south, and at the same time the vertical bands of quartzite are thrown into a series of folds. The result of this plication is to carry the boundary of the quartzite from Ballochford to a point near Burntreble farmhouse, whence it has been traced north-eastwards as far as the Hill of Dumeath, a distance of four miles.

The road from Dufftown to the Cabrach passes to the south of the Meikle Balloch Hill through the "Glack," and at this point the white quartzite is converted for some distance into a fault breccia composed of sharp angular fragments of quartzite of various dimensions embedded in a siliceous-felspathic matrix.

The angular debris and occasional exposures of rock seen on the high ground to the east of Glenmarkie indicate that the ridge that extends northwards from Garbet Hill to Gallow Hill, and the upper part of the eastern slopes of the glen, are occupied by quartzite, but the position of the boundary line between this rock and the black schist is obscured by the almost uniform covering of peat and heather. Thick-bedded quartzites first appear in the stream section below Burnside of Markie, where they dip E. 28 N. at 50°, and from this point to the Mill of Invermarkie bands of quartzite alternate with black schist and thin sills of foliated diorite. To the north of this section the bands of quartzite become vertical, and this rock covers the whole of the Tips of Corsemaul as far as Bodylair and "the Crofts." Between these two localities and the hill of Dumeath this zone of quartzite divides into two separate belts. Both of these pass into sheet 86, the northern one at Blacklug, and the other at the Wood of Straitinnan. On the east side of Glen Fiddich the Scaut Hill is covered with a very fine-grained crystalline granulitic

yellowish quartzite. A local base to the quartzite is indicated by the coarse pebbly grit, almost a conglomerate, that occurs on the ridge of the Black Hill in the south-east corner of the map. The rock is not actually seen in place, but the large angular masses which protrude in profusion through the peat that covers the hill top indicate its presence below. The well rounded pebbles are sometimes as much as 4 or 5 inches in diameter and are chiefly composed of white quartzite, suggesting that this rock is due to local erosion. Its local character is also shown by the fact that less than a mile to the east it passes along the strike into quartz-schist. To the north of this hill a narrow and much folded belt of grey and white quartzite forms the division between the black schist and phyllites. The small lenticular band which stretches from Bridgend in the valley of Burn Treble, west of the Deveron, to the Kelman Hill is a grey foliated schistose grit. It lies on the same line of strike and is evidently an infold of the Blackwater beds. Below the Mill of Lyneburn on the Deveron thin bands of a similar schistose grit are found associated with the black schist. J. S. G. W.

### Limestone.

The main outcrop of limestone in the area east of the Spey extends in a narrow and almost continuous belt from the head of Glen Tervie through Glen Rinnes and along the Dullan Water to Dufftown; and thence by Loch Park and the valley of the Isla to Keith. On both sides of this belt there are numerous small isolated bands and small lenticular areas of limestone which are associated either with the black schists or with the phyllites. The main outcrop varies considerably in breadth, this variation being partly due to the conditions under which the limestone was originally deposited, and partly to the intense overfolding to which it has subsequently been subjected. A description of the Banffshire limestone is given in the explanation to sheet 75, in which it is pointed out how a small band, originally of no great thickness, may through repetition by folding be made to occupy a very large extent of ground.

The limestones which are wrought or burnt for lime throughout this district are very uniform in character; they are highly crystalline, and vary from light to blue grey in colour. They often show distinct bedding-planes and bands of light and dark grey schist. In some localities this rock has been brecciated and re-cemented together by calcite, while in other places the bedded limestone is traversed by large veins and eyes of pink calcite. The less pure bands are generally dark, much thinner, weather with a rusty brown colour, and are often associated with black schists. No contact minerals have been observed in the main outcrop of this rock where it is in close proximity to the Ben Rinnes granite, but their absence may be due to the comparative purity of the limestone.

At the head of Glen Rinnes, below Nether Auchmore, several strong springs locally known as the "Lagantoul Wells" flow from the limestone. In a neighbouring quarry the rock is a grey saccharoidal bedded limestone traversed by veins of calcite. From this

point northwards the belt has been traced chiefly by small quarry openings, but at Succoth there are several good exposures in the Dullan Water. In all these the beds dip to the south-east. Below Allamichie a white and blue crystalline limestone shows colour-banding. At Nether Cluny this belt crosses from the right to the left side of the Dullan Water, where a solid blue and white limestone appears which has been quarried and burnt for lime. Along the bed of this stream the limestone has been worn into numerous pot-holes. Within a short distance, at the wood above Pittyvaich, the rock passes into a contorted limestone with thin calcareous and black-schist partings. The local crumpling seen at this point is the first indication of the numerous large folds into which this zone has been thrown in the neighbourhood of Dufftown, about a mile to the north-east. To the west of the Glack of Pitglassie, in the Dullan section, there are several infolds of the limestone, in which the rocks are much contorted, and exhibit signs of considerable movement. To the west of the point where the Dullan Water turns sharply to the north, and where a spur of the limestone projects into the stream, there are numerous very fine potholes, two of which may be seen on the face of the cliff, one above the other, marking different levels of the water as the stream cut down through the limestone. The upper one is locally known as the "Giant's Chair," and the lower as "Giant's Footstool." On both sides of the Dullan Water, at its junction with the river Fiddich, quarries in this band have been wrought for a long time and the stone burnt for lime. In the south or Richmond Quarry, a blue limestone, in thin beds with partings, dips below the black schist; while in the north or Tininver Quarry the rock is a solid blue crystalline limestone. Proceeding down the Fiddich section this rock for some distance is very much slickensided, contorted and folded. This is succeeded for about 200 yards by black schist in a similar condition, the result of the folding to which this belt to the east of Dufftown has been subjected. Immediately above the railway bridge the limestone is in a shattered and plicated condition; and on the opposite side of the river at Parkbeg a large lime quarry has been opened and wrought successfully for many years. Here the beds also show signs of considerable movement, are much slickensided, thrust over one another, and veined with calcite. A good exposure of this zone is afforded by the railway cutting along the side of Loch Park. Here the limestone is considerably shattered and folded, and where dip can be observed it is usually at a high angle. Intercalated with the limestone are black schists and thin calcareous bands with veins of white and pink calcite. A portion of the limestone is repeated between the foot of Loch Park and Drummuir Castle by several folds, which "nose-out" to the north-east of the castle; while at the same time the main outcrop sharply folds on itself at Midthird and then continues on to Drummuir Station. At this point the limestone is thrown into a compound fold and can be traced round both sides of the small quartzite area west of Forkins. In the small den west of Lower Towie there is a small infold of grey crystalline limestone with black schists, both showing con-

siderable plication. Here were situated the Drummuir Limeworks, but the quarry was abandoned about six years ago when the limestone to the north became exhausted.

At Poolside the beds which form the edge of this zone are the only ones exposed, and consist of calcareous schists dipping below black-schists. Limestone appears at Millcroft, and in the burn to the north of Coldhome an outcrop indicates the position of this zone as far as the limework at Braehead. This quarry has been opened in a grey crystalline limestone with thick partings of black-schist. A short distance to the south of it there are two infolds of dark limestone and calcareous schist. Almost at the point where this zone passes out of the sheet at the 500-feet contour line, there is a small opening in a bed of blue crystalline limestone dipping to the south-east. Another small infold of a similar rock occupies the bottom of the valley of the river Isla from near Blackhill Wood to the east of Fife-Keith. At the former point are situated the Maisley, and on the opposite bank of the river the Douglasbrae Limeworks, both of which are now abandoned. In each of the quarries attached to these works light grey crystalline limestone veined with calcite dips to the south-east. This is in turn overlaid by black-schist, and a similar section is exposed in the railway cutting east of Fife-Keith.

Isolated areas of limestone due to small infolds with the black-schist are found on both sides of the main outcrop. One of these occurs two miles to the west of Fife-Keith and close to the Mulben road, where there is a good exposure of a grey crystalline bedded limestone about twenty feet thick. This band is also seen crossing the Rosarie Burn. Another isolated band enters the sheet to the south of Keith and is quarried at the Blackhillock Limeworks. The workable rock is about 40 feet thick, and the beds are nearly horizontal. The grey limestone at Auchindown Castle in Glen Fiddich forms a craggy slope about 250 feet high, and a similar rock occurs on the same line of strike near Earnfold, where it is very much brecciated with small veins of hæmatite. The band which crops out in Glenmarkie below Belnaboyle is highly contorted and folded. It is a poor grey-white sandy limestone, but in proximity to the diorite it becomes much purer, and is almost converted into marble. A small band enters the map in the Glen Fiddich forest, while the small lenticular areas on both sides of the Hill of Clais nan Earb are doubtless isolated infolds of the same.

J. S. G. W.

## Black-Schist.

The largest area of black-schist in this map lies between Dufftown and Keith, and extends westwards to the centre of the Parish of Boharm. The general character of these rocks is that of a dark carbonaceous schist with some slate bands. The amount of carbonaceous material present in the rock constantly varies; it is generally more abundant in the region mentioned above, less so in the central area and increases again in the belt to the south-east.

Its rate of decrease is also very irregular, a very dark blue schist passing in a very short distance along the line of strike into a phyllite or mica-schist by the disappearance of the carbonaceous material.

Where these schists have a blue-black colour they are often distinctly graphitic. In many instances the original bedding planes can be recognised, especially in the less metamorphosed slates, but these are often obliterated by the subsequent foliation and the strain-slip-cleavage which has produced the corrugated structure so prominent a feature in the more schistose varieties. Garnets are tolerably abundant in these schists in certain localities, and there is also a sporadic development of secondary minerals such as actinolite, kyanite, andalusite, and staurolite. The more frequent occurrence of these accessory minerals in the neighbourhood of the Ben Rinnes granite, and the gabbros and diorites of the Blackwater and river Deveron, suggests their thermo-metamorphic origin. One of the best sections in this district is that afforded by the burn and its tributaries which joins the Fiddich at Mains of Newton, about a mile and a half to the east of Craigellachie. From the foot of this burn to the Mulben road the section displayed is entirely composed of soft, twisted, and corrugated coal-black schists with thin bands of limestone. These beds are strongly graphitic, and in two of the small streams above the bridge they contain a considerable quantity of iron pyrites, while several bands show finely developed crystals of actinolite up to four inches in length. At the foot of the small burn below Dinnyhorn black-schists with thin bands of limestone dipping north-east and south-east are succeeded by phyllites with strains and partings of black-schist and thin limestones. The rapid interfolding of the beds in this section results in the frequent repetition of the same bands. In the section at Knockan and in the two small burns immediately to the north similar folding is seen, and between the quartzite of Machatties Cairn and the phyllites of Mulben a comparatively thin portion of this zone is in this way made to occupy a considerable area. As these schists east of Auchlunkart House approach the foliated granite of Mulderie Hill they become garnetiferous, and alternate with bands of mica-schist. A very good section of these schists, with minute puckering and folding along the foliation planes, is displayed in the burn to the west of Cabbachs. From the line of fault north of Craigellachie north to Auchlunkart the western boundary of this zone is well defined, and in many of the small streams intersected by this divisional line the phyllites are seen dipping in below the black-schists.

The small burn that joins the river Fiddich immediately to the north of the Farm of Tulloch flows over dark schists full of iron pyrites, and the decomposition of this mineral gives rise to a thin efflorescent coating of alum on the rocky sides of the ravine, while the water which trickles over the rocks is strongly impregnated with the same salt. South of Balvenie Castle, on the left bank of the river Fiddich, there is a very fine section showing vertical and highly inclined bands of black-schist, which at the upper end of this

rock exposure are interfolded with the Dufftown limestone. In the stream below Auchanhandock, south-east of Dufftown, and also at its foot, bands of black-schist are found in contact with phyllites, but from the latter point to near Drummuir the line between this zone and the mica-schists is rather indefinite on account of the absence of rock exposures.

In the Drummuir Castle burn and also in that at Tenatown, black-schists with some thin quartzose bands are folded with thin beds of blue crystalline limestone. The triangular area around Starhead, north-east of Drummuir Station, affords numerous exposures of this schist, and in the small stream which joins the Burn of Davidston to the east of Howdoup the beds are very dark, carbonaceous, and finely corrugated. The alluvial flat which extends eastwards from Mulben to Newmill forms the northern boundary of this zone to within a mile from Fife-Keith. At this point the boundary line folds back upon itself for some distance and thence continues with a north-east course towards Keith. Close to this town, at the old limestone quarry of Braehead, this schist is very much twisted, and at Blackhillock and around the Cairds Wood it is very dark and often contains much graphite. At the southern margin of the map similar rocks occupy the col between the Tervie and Favat burns and extend northwards into Glen Rinnes as far as Succoth. In the burn of Balmerion they are very black, with intercalated bands of limestone. J. S. G. W.

Corrugated black-schists, more or less graphitic, are well exposed along the burn of Tervie, whose course between Tomachlaven and Mains of Morinsh is parallel to the strike of the rocks. With them are intercalated numerous thin calcareous bands, and from Lagavaich a broad band of pure and highly crystallised blue-grey limestone, intensely folded and contorted, follows the course of the stream to the edge of the sheet. The exposures seen near the head of the Tervie Burn and in the small stream immediately south of Blackknowe, show that as these schists approach the southern boundary of the Glen Rinnes granite they become garnetiferous and also develop large and perfect crystals of staurolite and andalusite. The relation of these crystals to the puckering of the schist proves that they were formed subsequently to the movements which produced the puckering or *ausweichungsclivage*. L. W. H.

The central black-schist area extends in a north-east direction from near Auchindown Castle to Corsemaul and crosses the Hill of Mackalea into Glen Markie; the extremely irregular course represented by its outcrop being due to the rapid folding of the beds. Auchindown Castle stands upon a cliff formed of vertical beds of blue crystalline limestone, and in the ravine below, on both sides of this crag, bands of black-schist are seen dipping towards the limestone. The schists here and also at a point 600 yards lower down the Fiddich are spotted and contain small knots. The hill burn which joins the river Fiddich below the castle, gives a continuous rock exposure in which the beds have a general inclination to the south-east, the upper portion of the section being composed of slaty bands which are seen to pass below the yellow

quartzite that caps the top of the hill. Due west from the cairn on the Scalp Hill and about three hundred yards below the edge of the quartzite a considerable quarry has been opened in one of the slate bands. These slates show original bedding planes, are very badly cleaved, and partake more of the nature of a flagstone. This quarry is now abandoned. On the north-west shoulder of the Hill of Mackalea the same band has been recently opened out, but the quality of the slate is very indifferent. At Corsemaul, Raehutcheon, and Earnfold, thin lenticular bands of dark grey limestone are associated with these schists. In Glen Markie this black-schist, together with the dark impure limestone, is traversed by numerous sills of basic rock which have produced a certain amount of contact alteration in the schist.

At the head of the Corryhabbie Burn there is a considerable area of very dark black-schist with slate bands. The beds are inclined to the south-east and pass below the quartzite which lies between this glen and Glen Fiddich. At the Folds of Corryhabbie and along their line of strike, these beds are interfolded with and pass into grey flaggy phyllites. A small lenticular belt of grey and black slates with crumpled graphitic bands extends along the east side of Glen Fiddich and passes into the sheet to the south. Another band of black-schist crosses the south-east corner of the sheet from Ardwell to Succothbeg in the valley of the Deveron. At Lower Ardwell in the river section and alongside the turnpike road there are exposures of slates with knots and crystals of andalusite. This band crosses to the east side of the river Deveron, and towards the top of the Hillock of Echt burn very hard black-schists are seen passing into grey knotted and andalusite schists. In the streams around Succothbeg and Meikle-Gouls the schists are vertical, very black, and contain a considerable quantity of graphite. Below Beldornie Castle the river has cut a deep gorge through crumpled and contorted black-schists which show a considerable amount of contact-metamorphism, doubtless due to the proximity of the epidiorite of Wallakirk. J. S. G. W.

### Mica-Schists, Clay-Slates, and Phyllites.

The mica-schists, clay-slates, and phyllites on the east side of the river Spey form a distinct series by themselves. These different members pass so gradually from the one into the other that it has been found impossible to separate them on the ground, the mapping being rendered still more difficult in Lower Banffshire by the thick covering of drift.

The phyllites are best developed in the area which lies between Keith and the Old Red Sandstone region to the south-east of Fochabers. The most typical section is found in the railway cutting below Craighead to the west of Mulben Station, where the beds dip to E. 25 S. at an average angle of 30°. These schists vary in colour from light to dark grey, and are all very fine in texture; the bedding planes are well defined, and their surfaces show minute puckering of the lamellæ. At several points in this section the phyllites contain

strains of black-schist, and also thin calcareous bands up to ¼-inch in thickness. These latter are very siliceous, and in some instances approach the condition of a calc-silicate. At the east end of the section the schists alternate with a few bands of thin siliceous rock.

Phyllites also occupy the wedge-shaped area which extends south to near Craigellachie, and are generally inclined to the south-east. At Cummingston, and 1000 yards to the south-west of the Church of Boharm, good bands of clay-slate are associated with them. In the burn which flows from Gow Moss to Mills of Mulben the phyllites have black-schist partings and thin white calcareous bands, and similar calcareous beds are intercalated with purple phyllites at the foot of the burn of Forgie and below Newton. Midway between these two localities we find green unctuous schists with yellow streaks, while towards the head of this burn the phyllites become very fissile, the laminæ in some cases being no thicker than a sheet of paper. Thick, flaggy bands of clay-slate with schist partings are exposed in the burn to the east of Tarrymount, and in the vicinity of Foggie Moss some good bands of purple and green clay-slates have been quarried for roofing slate.

In the stream to the west of Newmill, north of Keith, knotted mica-schists overlie fine grey flaggy schists with very fine wavy crumpling on their bedding planes. In the river and railway section near the old railway station of Keith, phyllite and clay slate bands alternate; and along the same line of strike to the west of Fife-Keith these pass into strong grey mica-schists.

A well-marked belt of this schistose series stretches from a point near the head of Glen Rinnes to the eastern edge of the sheet at the Hill of Shenwall. From Corryhabbie to the Coulalt Wood the phyllites are very uniform in character; grey in colour, often thick bedded and flaggy, with a general dip to the east and south-east at varying angles. In the Dullan Water between Hardhaugh and Nether Cluny the section displays bands of grey mica-schist and calcareous phyllites with occasional bands of black-schist intimately twisted and interfolded. There is also a good exposure of this series in the river Fiddich below Tullochallum, and at its western extremity phyllites and black-schists are seen folded together. This is succeeded to the east by grey and flaggy phyllites with calcareous schists, some of the latter being so far altered by metamorphic action as to have been converted into calc-silicate-hornfels of which the principal component is tremolite (*see* Chap. VII.).

From the river Fiddich to the burn of Davidston the phyllites become flaggy, and are intercalated with bands of mica-schist. On the north side of the Hill of Bellyhack there are numerous rock exposures of crumpled flaggy garnetiferous mica-schist. In the deep ravine which lies to the south of the Mains of Pitlurg the rock slopes are composed of hard slaty green phyllites with calcareous bands and partings of mica-schist that have a general inclination to N. 10 W. The face of the quarry at the west end of this ravine is composed of grey and green flaggy phyllites with soft limy partings.

The thick phyllites retain their original bedding, while the calcareous partings show a distinct foliation at an oblique angle to their orignal planes of deposition. Thick-bedded garnetiferous mica-schists with partings of soft mica-schists containing actinolite occur at Mains of Davidston.

The zone of phyllites and mica-schists which enters this sheet in the Glen Fiddich Forest is very much folded, the beds being either vertical or inclined to south-east at high angles. On the hill to the south-west of the lodge a roofing-slate quarry has formerly been wrought in a dark clay-slate band. In the Burn Treble section the beds of grey phyllite are often vertical and contain thin bands of black-schist. J. S. G. W.

The rapid alternation of the different zones of this Banffshire series and the basic igneous rocks associated with them, produced by isoclinal folding at high angles, is well illustrated in the continuous rock section exposed along the Blackwater for nearly two miles above its junction with the Deveron.

Ascending the Blackwater from the bridge we find grey phyllites alternating with dark slaty schists containing incipient knots, and also several thin sills of basic rock, the whole arranged vertically, or inclined to the east at high angles. These are succeeded rather more than half-a-mile above the bridge by a lenticular infold of grey gritty quartzite or schistose grit, which is in contact on its eastern side with a basic sill containing calcite. This rock proves on microscopic examination to have lost none of its clastic character (*see* Chap. VII.). Bands of this grey grit appear along successive isoclinal folds and are repeated five times between this point and the alluvial flat beneath the ruined buildings a mile higher up the stream. The portions of the section between the grit outcrops are occupied by alternations of phyllite, black slate, knotted and andalusite schist, with several gabbro sills. L. W. H.

In the south-east corner of the sheet, and to the north-east of the Craigwater Hill, the phyllites and black-schists are often knotted, and also contain scattered crystals of andalusite.

J. S. G. W

# CHAPTER V.

*Metamorphic Rocks—continued.*

## Granulitic Schists of the Central Highlands

The assemblage of rocks which occupy the ground on either side of the Spey and Avon in the south-west portion of the map are those which have been described in the explanation of the sheet to the south (75) under the name of the Cromdale Hills Series. As this series is now regarded as part of the wide-spread group of Central Highland rocks of Moine Schist type, it has been thought advisable to discard this purely local designation.

They may be described as a siliceous series in which quartz is generally the chief constituent, but variable in character between quartzites, mica-schists, and gneissose flagstones, according to the relative amount and disposition of the felspar and micas present in them.

Though the original clastic structure in these rocks has been obliterated by subsequent movement, and they are now holocrystalline and completely granulitic in character, the planes of original bedding are still often recognisable in the form of colour bands and dark laminæ. In the flagstones of the burn of the Cowlatt, near Knockando, north-west of the Spey, planes of false or current bedding are clearly indicated by lines oblique to the bedding planes. These dark laminæ when examined under the microscope are found to be composed of heavy residual minerals such as ilmenite, rutile, and zircon, thus offering a conclusive proof of the sedimentary origin of the rocks in which they occur.

The constant variation in the nature of these rocks is to a considerable degree no doubt due to original differences in sedimentation, but may also be attributed to the effects of subsequent mechanical movement. The area is one of intense plication, in which the rocks have been thrown into a series of complex flattened isoclinal folds, along the different limbs of which the differential movement and consequent deformation varies in amount. So rapid is the repetition of these folds, that where their crests are not visible, or have been removed by denudation, the appearance produced is that of regular parallel bedding with a general inclination to the east.

The double-shafted arrows used in this portion of the map do not however represent the dip of the original planes of deposition, but indicate the inclination of the foliation planes, which may, and indeed often do, coincide at any point along the limbs of the folds with the bedding planes.

The varying character of the rocks as affected by this intense plication, is admirably displayed in the deep ravines at the head of the Tormore Burn on the west side of Cragganmore, near Ballindalloch. The arches of the minor folds are occupied by lenticular cores of comparatively unmoved quartzite, which passes along either attenuated limb of the fold into a fissile quartzo-felspathic schist, in which white mica has been plentifully developed under the increased shearing strain. The result of this process, continued throughout the different portions of a set of compressed overfolds, will obviously be the production of a series of rapidly alternating bands of quartzite and quartz-mica-schist, such as we find here and in several other of the stream-sections of the Cromdale Hills.* A quarry in the wood on the north-west side of Cragganmore, 1¼ miles south of Ballindalloch Station, also gives a good section of the overfolded and sheared quartzites, associated with rocks of the gneissose flagstone series containing two micas and much felspar.

The main outcrop of the gneissose flagstones is found along the valley of the Avon and crosses the lower part of Glenlivet. The rocks are visible at many points along the stream between Drumin and Mill of Tommore. The apparent dip of the beds is generally at a high angle and at the mouth of the Livet Water nearly vertical. The inclination is towards the east except near Craggan, where one of the few instances of a reversed westerly dip occurs. These flaggy beds are also well seen in the Livet Water, one mile above Drumin, where they are exposed on either side of the stream between the old and new bridges, and are inclined to south-east at angles of 15°—40°.

The quartzose members of the group appear again on the eastern side of Strathavon, and form the hills above Morinsh and the south-west slopes of Ben Rinnes. Much of this ground is covered with peat and drift, and rock exposures are not abundant. The scars and rocky gullies on the north face of Cairnacay are formed of a tolerably massive and very crystalline yellowish quartzite which weathers with a white crust. This rock is somewhat similar in outward appearance to the quartzite of the Banffshire series, but a closer examination reveals the presence of black mica disseminated in minute flakes through the rock, while where the quartzite is more sheared white mica is developed along the planes of movement. On the Hill of Deskie, the slopes of Corshellach, and Cairn Mulgainich the shearing is more pronounced and the rock much more schistose; while striping, produced by the drawing out of the mineral particles in one determinate direction, is often well seen, the direction of movement being to the north-west.

On the west side of the Cromdale Range the mica-schists are more predominant, but owing to the amount of drift that covers the hillsides it is not often possible to separate them from the more siliceous members of the series. The approximate boundaries of one of the larger belts of mica-schist are shown on the map along the western slopes of Creag an Tarmachain, and the rock is exposed in a fairly continuous section in the Burn of Coire Seileach and its

* See Explanation of Sheet 75, p. 18.

tributaries. The flaggy quartzites and quartz-schists that are seen at intervals along the course of the main stream above the bridge at Advie Mains, are succeeded two miles south of the bridge by a fine-grained fissile mica-schist, containing small garnets, and aggregations of mica in the form of incipient knots. The schist is puckered and cleaved, and the cleavage planes are oblique to the planes of foliation. A good section of these schists is also given by the first tributary burn on the right (Burn of Garvault on the six-inch map). The apparent dip is south of east at somewhat low angles, and near the head of the stream the schists are succeeded by sheared quartzite with almost horizontal folding.

Crossing the river Spey we find the extreme south-west margin of the map occupied by a grey muscovite-biotite-gneiss, fine-grained, and thoroughly granulitic. The rock is only visible in a few places on the hill slopes two miles north of Auchnagallin, but is extensively displayed just beyond the western limit of the sheet, in the Cree Dearg and on Carnghille Chearr, where it is in a high state of crystallization and filled with veins of reddish biotite-granite.

The somewhat conjectural boundary-line drawn northwards along the drift-covered slopes of Carn an Loin and Carn Ruigh an Uain, separates these gneisses from the siliceous rocks of Moine Schist type which cover a wide area to the north and east, extending over the high moorlands which lie between the Spey and the head waters of the Lossie. A large part of this area is uniformly covered with hill-peat and thick drift, and it is only where the hill streams have cut deeply through these superficial deposits that the rocks are laid bare. The prevailing type of rock in this region is a more or less felspathic quartzite or quartz-schist, in which biotite, disseminated through the rock in minute specks or flakes, is a constant though not abundant constituent. The amount of shearing and interstitial movement constantly varies, and the rock passes rapidly from a comparatively unmoved and massive quartzite into a thoroughly schistose rock in which white mica is abundantly developed along the planes of movement.

The Burn of Tulchan and its tributaries afford perhaps the most continuous section of these rocks. In the deep ravines cut by the head waters of the stream the granulitic quartzite shows signs of much deformation and has been rendered thoroughly schistose. These schistose quartzites contain pink felspar and abundant white mica. The burn of the Black Loch runs for some distance along a line of fault, in the neighbourhood of which the quartzites are much shattered and disturbed. Below the junction of the Allt an Loin Mhor the quartzite is far less schistose in character, and at Delyorn becomes a massive rock showing hardly any traces of movement. Bands and thin seams of mica-schist or fine-grained gneiss are freely intercalated with the quartzites, and are sometimes of sufficient breadth to be indicated on the map, as at the Hill of Knocktulchan. A similar section is afforded by the Allt Gheallaidh, but here the rocks are much concealed by drift along the upper part of the stream. Compressed folding in the quartzite is well seen in this section at the foot of Paul's Hill, and also a short distance

above Pitchroy Mill. At the latter locality a band of grey mica-schist with small knots or aggregations is folded with the quartzites.

These siliceous strata can also be observed at several localities along the course of the Spey, as at Dalvey, Tulchan Lodge, Achvochkie, the Craigs of Callander, and Delnapot. A good section is laid bare on the western side of the Pool of Bundearg immediately below the junction of the Avon with the Spey. Here massive, banded, purplish quartzites alternate with cleaved mica-schists. The dark bands in the quartzite distinctly indicate lines of original bedding, and the cleavage planes in the schist, which are oblique to the other divisional planes, do not pass into the former rock. Below Dalgarvon, where the river takes a sudden bend to the east, the rocks become more gneissose in their general character. Fine-grained granulitic biotite and muscovite-biotite gneisses, with occasional intercalations of more siliceous rock, appear at Knockando House, Laggan, and several other points along the course of the Spey between the mouth of the Knockando Burn and the western boundary of the Ben Rinnes granite. L.W.H.

### Undifferentiated Schists.

From Knockando northwards to the Black Burn beyond Dallas, the metamorphic rocks consist of quartzo-micaceous-schists, with broad bands of muscovite-biotite-schist which have been separated out from the more siliceous rocks. In the north-west corner of the map there is a small area of holocrystalline felspathic quartzite. The west end of the Eildon Hill is composed of a very hard pink quartzite alternating with micaceous flaggy bands, and, associated with these, a belt of grey flaggy mica-schist stretches from Rafford to the Monaughty Wood. This rock is a coarse flaky muscovite-biotite-schist or gneiss, with wavy folia. It often contains garnets, and is extremely rich in mica, and in its lithological character closely resembles the muscovite-biotite-gneiss which has been separated from the Moine schists in the survey of the Central Highlands.

The rocks around Westerton House, Black Burn, are flaggy quartzose and micaceous schists with bands of pink quartzite, and similar massive pink quartzites with pegmatite veins form the rocky slopes which surround the water reservoir at Farnaley. To the south of Blackhillock, near the head of the Black Burn, there are fine flaggy quartz-schists with colour-banding parallel to the foliation planes, which are intersected by small granite dykes and veins. These schists lie between two broad belts of muscovite-biotite-gneiss, massive and tough in character, and containing numerous lenticles and strings of quartzo-felspathic material developed along the foliation planes.

Very little rock is seen in the valley of the Lossie, but its tributary, the Lennoc Burn, affords a good section for several miles. At the head of the stream flaggy gneisses with several bands of crumpled muscovite-biotite-gneiss are inclined to the north-west at an average angle of 25°, and are succeeded by a series of hard, grey, massive quartzites and quartz schists with small granite veins. The Glen-

latterach waterfall is produced by a very massive band of quartzite dipping to north-east, over which the stream precipitates itself into a ravine whose sides are formed by rocky cliffs 100 feet in height. For some distance below the cascade the beds are vertical, but lower down, towards the mouth of the stream, dip north and north-west at 20° to 60°, and are chiefly grey gneissose flags with colour banding parallel to the foliation planes. Below the crofts of Buinach the river Lossie flows for some distance over a rocky floor composed of hard, grey, massive and flaggy quartzites. In the Gedloch and Shougle Burns, east of the Lossie, the beds are holocrystalline, granulitic, micaceous flagstones, with bands of hard, massive quartzite. At the upper end of the "Slogg" of Gedloch the rock face of the ravine shows a fine pink quartzite very much brecciated, and not unlike the "Cone Rock" at Rothes.

Between Birchfield and east of Hart Hill the rocks along the line of the Glen Rothes fault are very much disturbed and shattered, and are mainly composed of pink and dark grey massive quartzites with bands of more micaceous material. These are uniformly holocrystalline and granulitic in structure, and are associated with numerous small bands and one broad belt of muscovite-biotite-gneiss.

In the Back Burn of Rothes massive quartzites and quartz-schist veined with granite are inclined to east and south-east, and apparently overlie a band of very fine light-grey muscovite-biotite-gneiss with small garnets, which is succeeded by grey micaceous flagstones with veins of granite and quartz. About a mile to the west of the village the Rothes Burn runs between high cliffs of rather decomposed flaggy micaceous schist, often very gneissose, and traversed by numerous small quartz and granite veins. Above Doony Hall the rock passes into muscovite-biotite-gneiss traversed by numerous dykes, veins, and lenticles of granite, and within half-a-mile of the Netherly diorite it is pierced by several small bosses of pink granite. In the burn of the Coulatt there is an outcrop of drab-grey, very fine-grained quartzites. These are distinctly bedded, and in some cases show false bedding oblique to the ordinary planes of deposition.

Dr. Mackie* of Elgin has made an elaborate investigation of the granite veins and contact rocks of the Back Burn of Rothes. Chemical analyses were made by Dr. Mackie from five veins (2 biotite-bearing veins, and 3 muscovite-bearing or pegmatite veins), and specimens were selected from the centre and margin of the veins along with "proximal" and "distal" specimens from the quartz-schist alongside. The general results obtained were that the marginal zones of the veins are considerably more basic than the centre, and in the marginal rocks the "proximal" specimens are more basic than the "distal" ones. The veins are also richer in potash at their margins than in the centres, and in the contact rocks there is a marked excess of this element in the "proximal" as compared with the "distal" analyses, indicating an outward flow of potash.

J. S. G. W.

* Trans. Edinburgh Geol. Society, Vol. viii., Part i., p. 98.

# CHAPTER VI.

## *IGNEOUS ROCKS.*

The igneous rocks found within the area under consideration may be conveniently arranged in two classes, according as they are shown by their structure to be earlier or later than the earth movements that have affected the schistose rocks of the region.

The older plutonic intrusions of acid type consist of foliated muscovite-granite or augen gneiss; the basic rocks are represented by sills of foliated gabbro, epidiorite, and serpentine. The newer igneous masses include the great central area of the Ben Rinnes granite with its apophyses and marginal basic modifications on the north-east; the small tract of unfoliated quartz-mica-diorite and serpentine in the extreme south-west corner of the map; a few later dykes of lamprophyre; and a contemporaneous andesite of Old Red Sandstone age. L. W. H.

### 1. Older Plutonic Masses.

Epidiorites.—The general character of the epidiorite in this sheet is that of a fine-grained crystalline rock. It varies in colour from light to dark green, and in several localities contains garnets. It occurs in the Deveron Valley in small separate bosses and also as a portion of the western margin of the large Huntly area (sheet 86). In the Blackwater and Glen Markie sections there are numerous small sills of this rock. From the foot of the burn of Edinglassie in the valley of the Deveron to the Westerfolds, a small tongue of the large epidiorite area to the east enters this sheet. A specimen from Westfolds shows the rock to be a fine-grained dark green foliated epidiorite or hornblende schist. At the foot of the burn of Edinglassie this rock becomes very massive and has all the appearance of an altered rock with contact minerals. It is quite possible that the foliated granite at Quarryhead may have been the cause of this alteration. Further up the Deveron, near Wallakirk, there is a similar area of epidiorite which when traced to the south-west passes into the serpentinised gabbro of Craigs of Succoth and Craigdorney. In the Markie Water section numerous small sills and masses of epidiorite with garnets are intercalated with the black-schists and limestone of Glen Markie. At the Newton of Glen Markie the rock is very massive and fine grained. In the burn which runs past the farmhouse of Findouran there is an exposure of a grey green very finely foliated hornblende schist which appears along the edge of the belt of gabbro (No. 9565, *see* Chap. VII.).

GABBRO.—At Craigs of Succoth this rock produces bold craggy features on both sides of the river. At Craigdorney it is a medium-grained dark grey peridotite, partially serpentinised in places. It consists principally of diallage and olivine, the latter mineral in places still remarkably fresh (No. 9563, *see* Chap. VII.). On the east side of the Brown Hill the three craigs of Belcherrie, Succoth, and Line rise above the surrounding turf-peat and heather, and consist chiefly of dark green serpentine with a little gabbro. To the south this serpentine passes into a gabbro.

J. S. G. W.

The river Blackwater, from its junction with the Deveron to the edge of the map, affords a good section of the series of basic sills which form the northern prolongation of the sill of gabbro and epidiorite that crosses sheet 75, and has been fully described in the explanation accompanying that sheet.

These rocks, though considerably altered, belong generally to the pyroxene rather than to the amphibole group. The most basic portions are more or less serpentinised, though this form of alteration is not so complete as in the masses of serpentine seen around Blackwater Lodge, a mile or two further south. Microscopic examination of some of these serpentines shows that they have resulted from the decomposition of pyroxenes (*see* Chap. VII.). In other cases the serpentine has possibly been derived, by a process of selective metamorphism, from the olivine-bearing portions of the gabbro. Original crystals of olivine can still be occasionally recognised in the former rock, while this mineral appears to be absent from the gabbro where the latter shows no trace of serpentinization (2963, 2964).

GABBRO.—The broad sill that follows the course of the Blackwater from the point where it bends to the south to the edge of the sheet is composed of a partially uralitised gabbro. Under the microscope the rock appears as a holocrystalline aggregate of plagioclase and augite, the former being the predominant constituent. The augite, which is a diallagic variety, occurs in irregular masses and grains sometimes enclosed within the plagioclase, and is mostly of a turbid brown colour. Along the periphery of the crystals it is often altered into a fibrous green hornblende, which also occurs in confused masses of fibres and minute needles. At the foot of the small burn which joins the main stream on the west, rather more than half-a-mile from the margin of the map, the rock is coarsely crystalline, and contains large individuals of a greenish mineral. Here also the augite is mostly altered into green or brown acicular and fibrous hornblende, and it is these aggregates of actinolitic hornblende which give rise to the green silky patches that are so conspicuous in the rock. The wavy appearance of the striæ of some of the augites is suggestive of internal movement due to extraneous pressure.

Parallel structure is everywhere more or less apparent in these gabbros, but the foliation is more complete along certain bands which, in the coarser portions of the rock, recall the beautiful foliated gabbro of Pooldhulie in Strath Don.

L. W. H.

Foliated Granite.—The foliated granite to the west of Keith occupies a long oval area which extends from Auchlunkart Lodge to North Bogbain and embraces the upper portion of the Hill of Mulderie. The best exposures of this rock are to be seen in several small quarries to the east of Midtown and at the head of the small burn which runs past Cullieshangan. At the former locality the foliation planes are inclined E. 28 S. at 45°. The rock is partially decomposed and is a light-brown coarse granitoid micaceous gneiss with more or less isolated and drawn-out augen-shaped masses or kernels of felspar. (Some notes on its microscopic characters will be found in Chap. VII.)

To the east of Fife-Keith on the banks of the river Isla, and in a quarry between the railway station and the edge of the sheet, there are good exposures of a belt of foliated granite identical with that seen at Mulderie. The foliation planes vary considerably in their direction from E. 5 N. to S. 8 W. with an average angle of 30°. Parallel to this band and about 400 yards to the east a similar zone extends from near Coldhome to the north-east of Keith, and is in all probability the Fife-Keith belt repeated by folding. The best section is seen in the quarry to the south of the Roman Catholic Chapel, where the rock is a fine-grained silvery grey gneiss.

Between the Carran and Bellyhack Hills the ground is covered with numerous angular blocks of this foliated granite, and although no rock is actually seen in place its presence is inferred from the abundance of the loose debris. The quarryhill to the west of Invermarkie is also covered by debris of augen gneiss.

J. S. G. W.

## Newer Plutonic Rocks.

Granite.—The great central mass of granite forms two areas of unequal size lying on either side of the river Spey. They are probably continuous beneath the alluvium immediately opposite Aberlour, but between the mouth of the Ruthrie Burn and Laggan are separated at the surface by a thin strip or bridge of metamorphic rock which is seen in the steep northern bank of the river.

The larger area south of the Spey covers nearly 24 square miles of ground between Ben Rinnes and Dufftown. Its longer axis extends for six miles in a north-east direction, parallel to the strike of the schists. The northern mass occupies an area three miles by two in extent, of which the village of Archiestown is the centre. Its exact limits are somewhat uncertain, the position of the boundaries being generally obscured by drift. The boundary line drawn along the slopes of the Hunt and Stob Hills is indeed only an approximate one; since where the ground, as on the summit of Hunt Hill, is bare of drift it presents a plexus of igneous and metamorphic rocks, the interlacing veins and apophyses from the main mass of granite traversing and isolating portions of the surrounding schists in a most complex manner. That this is the nature of the junction all along the northern boundary of the granite is indicated by the innumerable veins seen in all the stream sections and wherever the rocks are exposed.

In none of these intrusions is there any appearance of a chilled edge; indeed the thin veins are as coarsely crystalline up to their margins as the interior portions of the main mass. The veins have usually been injected more or less along the planes of foliation, but occasionally a broader vein is seen to cut these latter at a high angle, sending out thin branch veins on either side along the planes of schistosity.

In addition to this direct introduction of igneous veins, the rocks along the granite border are often so much impregnated with granitic material that the structure becomes granitic rather than granulitic. This phenomenon is particularly noticeable at the bridge of Craigellachie and in the railway cutting close to the station, where this interstitial permeation is so complete that it is often difficult to distinguish the altered quartzite from the original igneous rock.

Quarries have recently been opened on the northern flanks of the Blue Hill of Aberlour, a few hundred yards from the northern edge of the Ben Rinnes granite, the intervening ground being filled with veins and apophyses from this igneous mass. The rock exposed in the quarries is a granulitic muscovite-biotite-gneiss or schist, generally fine grained and tolerably siliceous, but with occasional coarse and more gneissose bands. It is filled with parallel veins or bands of granitic quartzo-felspathic material varying from less than ¼-inch to one foot in thickness. They are generally parallel to the foliation-planes of the schist, but occasionally send branches or strings across from one vein to another. The thicker veins tend to become coarser in the centre, but nothing like a chilled edge exists, and an interlocking of the marginal crystals of the vein with those of the surrounding schist can often be detected.

Certain of the veins swell out at intervals into lenticular or eye-shaped masses, some of which seem to be isolated from one another, while others are connected by a thin string of the same material. These "augen"-like masses are generally sheathed or surrounded by thin bands in which biotite is considerably more abundant than in the rest of the rock; suggesting a separation of the more acid from the ferro-magnesian minerals along certain lines.

While the direct intrusion of granitic material along the lines of discontinuity in the schists has usually been suggested as the cause of these phenomena, it is possible that they may also be due to segregation of the quartzo-felspathic elements in the surrounding rock. Whether we attribute these appearances to direct intrusion, to segregation, or to a combination of both causes, we may with certainty assume that they are intimately connected with the period of intrusion of the Ben Rinnes granite, and are of later origin than the movements which produced the schistosity of the rocks in which they appear.

The principal constituents of the ordinary type of Ben Rinnes granite are quartz, orthoclase and oligoclase felspar, and biotite; the last named mineral being generally scanty, and sometimes altogether absent. Varieties of the granite also occur in which microcline, muscovite, sphene, and allanite are present (*see* Chap. VII.).

The differentiation of the original magma of the Ben Rinnes granite seems to have proceeded on similar lines to that observed in connection with many other intrusive masses in the Eastern and Central Highlands. Intrusions of basic rock are represented on the map as occurring along the burn of Rothes at Netherly and on the Hill of Stob, immediately to the north of the granite area of Archiestown and the Hunt Hill. On the Hill of Stob the rock is a typical diorite of which the essential constituents are hornblende, biotite, and plagioclase; at Netherly we find a more acid type, a moderately coarse-grained quartz-biotite-diorite, in which the biotite often occurs in very large individuals. Both varieties are thoroughly granitoid in character and show no signs of alteration or paralle structure. The bed of the burn of Rothes is filled for a distance of nearly a mile with large sub-angular masses of the mica-diorite, but the rock is only seen actually in place at one point near the western limit of the area. The Hill of Stob diorite also only occurs in large weathered blocks on the surface, but there is strong presumption that the rock is in place below.

The mutual relations of these two basic masses, and of both with the granite of the Hunt Hill, cannot be clearly determined, the intervening ground being so thickly covered with drift that no rock is seen even in the stream sections; but the similarity in condition of crystallisation and of structure is in favour of their origin from a common magma, and of their continuity beneath the superficial covering.

The surface of the ground on the wooded hilltop above the Cone Rock, south of Rothes, is thickly strewn with masses of diorite. probably weathered out in place, though the rock is nowhere actually seen *in situ*. The chief constituents of this rock are felspar, green hornblende, and quartz, with sphene as an abundant accessory; and from the amount of orthoclase present it may be regarded as a syenite. Another small exposure of a somewhat similar rock is seen along the roadside between Dandaleith Station and the Bridge of Craigellachie. It varies a good deal in character. The prevalent type is quartz-diorite, in which orthoclase is always present, and sometimes in such abundance that the rock becomes a syenite.

These varieties from the two localities described above have been regarded as intermediate or passage forms between the Netherly diorite and the granite of Hunt Hill and Ben Rinnes; and the evidence afforded by the microscopical examination, as adduced in the Petrographical chapter, serves strongly to support the conclusions arrived at during the field work.

The granite of Ben Rinnes is closely similar both in character and mineral composition to the granite of the Cairngorm Mountains. The differentiation of the magma, as already indicated, is also similar to that found along the southern margin of the Cairngorm granite; where the same passage from biotite granite through syenite or tonalite into typical diorite has been described from Glen Gairn and Upper Deeside.* The marginal phenomena

* Geol. Survey Summary of Progress, 1899–1900.

seen on Hunt Hill and round Craigellachie also strongly recall the complex system of apophyses, inclusions, and detached veins observed along the edge of the Monadhliath granite mass at Aviemore, and at Loch Builg in the Eastern Cairngorms.

Owing to the want of exposures, the contact zone of the Ben Rinnes granite and the Banffshire series affords little evidence of thermo-metamorphism; but in the region north of the Spey the Netherly diorite has produced hornfelsing in those portions of the surrounding schists that were from their original composition capable of being altered in this manner. The minerals found in the andalusite and cordierite-hornfels in the burn of Rothes are essentially the same as those of the cordierite rocks near the Cairngorm granite in sheet 75 (*see* Chap. VII.). Another characteristic feature of the Cairngorm granite is found in the "scurrans" or weathered rock-masses that crown the summit of Ben Rinnes and show well-marked tabular weathering along their horizontal joints.

The facts adduced above show the striking resemblance in composition, variation, and relations with the surrounding rocks that exist between the Ben Rinnes and Cairngorm granites, and indicate the close relationship of the two masses. It therefore seems highly probable that the former, as well as other outlying masses to the north and west, belong to the period of intrusion of the great granite area in the south; and further, may, as suggested some years ago in the explanation to sheet 75, be regarded as protrusions from an underlying and continuous floor of igneous rock.

Along the banks of the Spey at Carron, Dalmunach, Pool Leek, and Creag Neach; in the cutting under Knockando House; and beneath the alluvium near Dalbeallie Station, the quartz flagstones are pierced by numerous veins and sills of red granitite containing orthoclase, oligoclase, quartz, and abundant biotite. In the crag that overhangs Pool Leek the junction between the two rocks is well seen. The quartzite at the water's edge rests upon the upper surface of a sill of granite which is coarse-grained to the edge and shows no sign of a chilled margin. A small outlying mass of the Ben Rinnes granite is also found at Parkhead, half-a-mile north of Glen Farclas Distillery. It contains inclusions of quartz-schist, but is much decomposed, and is quarried at the roadside for sand.

Diorite.—The small patch of basic igneous rock that crosses the extreme south-east corner of the map at Three Burnshead How, forms part of a large area of quartz-mica-diorite lying to the south of the Tap of Noth in the adjoining sheets (76,86). It is a coarse granitoid rock of which the essential constituents are quartz, plagioclase, biotite, and hornblende, with no signs of parallel structure, and shows the characteristic weathering into spheroidal masses common to so many of the Aberdeenshire diorites. The serpentine that appears on the east side of the diorite is possibly an altered ultra-basic modification of the same intrusion, but the boundary and relations between the two rocks are obscured by the thick covering of boulder-clay.

The evidence is in favour of separating these rocks from the foliated epidiorites and gabbros of the Deveron and Blackwater, and assigning them to a later period of intrusion.

LAMPROPHYRE.—In the quartz-schists that form the steep cliff that rises above the Spey at Hollybush Pool, about three-fourths of a mile east of Aikenway, there are three or four thin sills of a fine-grained greenish-red basic rock generally much decomposed. The rock is indicated on the map as a camptonite, but from its character under the microscope it is regarded by Dr. Flett as a dioritic lamprophyre. The microscopic characters and systematic position of this rock are discussed in Chapter VII. L. W. H.

# CHAPTER VII.

## *PETROGRAPHY OF THE AREA.*

### I. The Later Granites and Diorites.

Of the newer granites which date from a period subsequent to the development of the foliation, and hence present the usual structures of plutonic igneous masses, only one great mass exists in this area, that of Ben Rinnes and the Convals. The smaller intrusions at Netherly, Dandaleith, etc., though more basic in character, show so many evidences of consanguinity to the more acid type that they are best regarded as its marginal modifications. A complete series of gradations from the most acid muscovite pegmatites to the quartz-augite-diorites can be traced in the microscopic sections, and leaves no room for doubt that they have a genetic relationship. A similar association is well known in the granite of the Cairngorms,* the Southern Uplands,† Garabal Hill,‡ and elsewhere in Scotland.

The Ben Rinnes granite, as seen on the northern slopes of that mountain and in the vicinity of Aberlour, is mostly a flesh-coloured biotite granite, of medium grain and rich in quartz; while biotite, the only dark-coloured ferro-magnesian silicate, is never present in great quantity, and is sometimes almost absent. Both in the hand specimens and under the microscope it closely resembles the Cairngorm granite, of which it is in all probability an outlying mass. Its principal ingredient is a flesh-coloured felspar, which occasionally shows a tendency to porphyritic development, and proves to be mostly orthoclase with subordinate oligoclase. Microcline is not common, the orthoclase is often perthitic and surrounds the acid plagioclase; muscovite is very scarce, and for the most part secondary. A little micropegmatite (quartz vermiculé) is not infrequent. Occasionally the hand specimens show an ill-defined parallel structure, and under the microscope traces of cataclastic action are rarely entirely absent.

Taken as a whole, the Ben Rinnes granite is exceedingly uniform throughout, but towards the margins of its outcrop varietal modifications of several kinds occur. Thus in the quarry at Ruthrie, Aberlour, a grey granite is obtained, obviously richer in biotite than the granite of Ben Rinnes, from which also the pearly-white or grey colour of its felspar distinguishes it. This granite

* Memoirs of the Geological Survey, Scotland. Explanation of Sheet 75 by Lionel W. Hinxman, B.A., with a Petrological Chapter by J. J. H. Teall, M.A., F.R.S. 1896.

† Memoirs of the Geological Survey. The Silurian Rocks, Vol. i., Scotland. By B. N. Peach, F.R.S., and John Horne, F.R.S.

‡ The Plutonic Rocks of Garabal Hill and Meall Breac, by J. J. H. Teall, F.R.S., and J. R. Dakyns. Quart. Jour. Geol. Soc., Vol. xxviii., p. 104.

is rich in sphene and allanite, the cherry-red grains of the former and black or coffee-brown prisms of the latter being easily detected on the surface of the hand specimens with the aid of a pocket lens. The sphenes are often in interpenetrating cross twins; the allanite in elongated dark-brown, zonal prisms, sometimes simply twinned on the orthopinakoid and slightly pleochroic. They are perfectly idiomorphic, the transverse sections being bounded by the usual six faces (001, 101, 100) and resembling hornblende in their outlines. This rock contains much oligoclase, perthitic orthoclase, and a little micropegmatite. The sections show no muscovite, and no cataclastic structures.

Allanite occurs also in the granite which forms a little mass at Carron on the Spey. In the rock slice one large prism is seen in longitudinal section. It has a dark-brown colour, and is highly zonal. The rock is a reddish biotite granite, not unlike that of Ben Rinnes but richer in biotite.

The muscovite granite of Nether Cluny, two miles S.S.W. of Dufftown, is of quite a different type. It is probably a vein or apophysis of the main mass, and is exposed in a small stream by the roadside in contact with a quartzite. Biotite is absent; muscovite, which is scarce in the Ben Rinnes granite, is here abundant, and the felspar is largely microcline. The rock is pale coloured, of medium grain, and the numerous plates of muscovite scattered over their surfaces give the hand specimens a very characteristic appearance. The quartz and felspar tend to occur in rather coarse graphic intergrowth. In the points in which it differs from the typical granite of Ben Rinnes, this rock approaches the aplites and muscovite pegmatites, of which there are many examples in the dykes of this region.

Hornblende has not been detected in the Ben Rinnes granite, with one interesting exception. A section was prepared from a small, rounded, dark coloured, fine-grained inclusion in a mass of granite at Milltown of Ruthrie, above Aberlour. It proved to be an intimate admixture of hornfelsed biotite gneiss with veins of diorite. Each of the two rocks preserves its characters, though the schist is surrounded and penetrated by the diorite. The latter is rather fine grained, rich in orthoclase and in sphene, which often encloses well formed, lath shaped plagioclase felspars, and in one crystal shows lamellar polysynthetic twinning parallel to the face of the prism (110). Hornblende is mostly idiomorphic, only rarely enclosing a felspar. Biotite, which is abundant in the schist, is practically absent from the diorite. In these features this rock closely resembles the syenites and diorites, which we now pass to consider.

At Dandaleith Station, along the roadside, half way to Craigellachie Bridge, there is a limited exposure of a dark-coloured dioritic rock, of which the principal ingredients are dark green hornblende, and flesh-coloured, or sometimes brick-red felspar. From this little mass several specimens were prepared, and as might be suspected from the hand specimens, it is not altogether uniform in character. The prevalent type is a quartz-diorite, consisting of green hornblende, plagioclase felspar, and varying

amounts of quartz. The structure is not ophitic, the hornblende having crystallised before the felspar, which it does not enclose. But orthoclase is never absent, and in some of the sections it is the dominant felspar: the rock might then be regarded as a syenite. The sections show no biotite: reddish pleochroic sphene is abundant and conspicuous in the hand specimens. It occurs in large ophitic plates, enclosing lath-shaped plagioclase felspars, and has a very perfect lamellar structure, which is evinced by straight, perfectly continuous cleavages parallel to the prism faces (110). This structure has usually been ascribed* to repeated twinning, and between crossed nicols it is obvious that the crystals are polysynthetic, the sections being crossed by numerous colour bands which run parallel to the cleavage, and may be in two series intersecting one another. Epidote is abundant in this rock, and has sometimes brown cores, which may be allanite. Stout, hexagonal prisms of apatite are frequent, and a few are crowded with minute dark enclosures, but these are far more characteristic of the diorite of Netherly.

In the wood above the Cone Rock, one mile south of Rothes, large blocks of diorite lie strewn over the surface of the ground, probably weathered out of a subjacent mass. This rock contains much grey felspar, abundant dark-green hornblende, and no biotite. It contains a fair amount of quartz, and so much orthoclase as to entitle it to be regarded as a syenite. Sphene is abundant, occasionally enclosing a felspar,† and shows the lamellar platy structure, with only traces of polysynthetic twinning. The hornblende is rather decomposed, chlorite and epidote being the products.

The diorite of Netherly is well exposed in the Rothes Burn, and is in the hand specimen a handsome rock with hornblende, black glancing biotite, and greyish quartz and felspar, of medium or rather coarse grain, and not porphyritic. It is a more normal diorite than those already described, as plagioclase, zonal and sometimes fairly basic, forms its principal felspar, though orthoclase is present in quite subordinate amount. The biotite sometimes encloses plagioclase, the hornblende as a rule does not. A little grey-green pyroxene occurs, enveloped in dark green hornblende. The one mineral is often found to enclose patches of the other, each then extinguishing simultaneously throughout, and probably they are in parallel intergrowth. In many cases the hornblende has paler centres, giving it a spotted appearance, and it is in every way probable that augite originally formed the cores of such crystals. The hornblende is similar in character to that in the diorite of Dandaleith, the augite shows no diallage lamination. Sphene is less frequent in this rock, and usually forms thin

* Williams, G. H. Cleavage in American Sphene. American Journal of Science, Vol. xxix., p. 486 (1885).
Mugge, O. Ueber durch Druch entstandene Zwillinge von Titanit. Neues Jahrbuch fur Mineralogie (1889), Band ii., p. 98.
Lawson, A. R. The Rainy Lake Region. Ann. Report of the Geol. Survey of Canada (1887), Pt. i., p. 124, Fig. 11.

† Mackie, W. On Differences of Composition between the Central and Marginal Portions of Granitic Veins. Trans. Edin. Geol. Soc., Vol. viii., Pt. i., p. 94.

rings around iron oxides. Apatite is very abundant in large, stout, idiomorphic prisms, which are so filled with little dark enclosures as to become quite opaque at their centres, while sometimes a thin external zone is perfectly clear and transparent. As a rule, these enclosures are too small to reveal their nature even under the highest powers, but the largest of them are fluid cavities with mobile bubbles. These apatites are not pleochroic, but similar crystals occur in a small intrusive mass or large vein which pierces the schists a little east of Craigellachie tunnel, and is exposed in the railway cutting; and here the pleochroism is marked, and as the nicol is rotated the section changes colour from pale yellow-brown to dark greyish-blue or black. Such apatites are more frequent in volcanic than in plutonic rocks.

The quartz of this diorite is often filled with dark hairs of rutile, a feature which constantly recurs in the plutonic masses in this area. The felspars also contain minute opaque enclosures regularly disposed in at least two series, with a definite orientation which could not be exactly determined. These, it may be pointed out, are characteristics also of the more basic rocks associated with the Galloway granites, to which the Elginshire diorites present a strong resemblance.

At Stob Hill, a little south of Netherly, a diorite is exposed, essentially similar to that just described, except in the greater abundance of biotite, which gives the rock a distinctive appearance. Here, too, sphene is not abundant; the apatites have numerous large fluid cavities, but are not dusty and opaque; the hornblende has often paler centres, which may have originated from a pyroxene, though that mineral was not present in the rock section. The felspars contain the regularly arranged opaque enclosures.

In the quartz diorites of Netherly and Stob Hill it is frequent to find the hornblende in spongy masses, the interstices of which are filled up with quartz or acid felspar (*see* Fig. 1). The structure is micropoikilitic, or often graphic, as the scattered patches of quartz may extinguish simultaneously. They may, moreover, be in optical continuity with areas of quartz surrounding the hornblende and filled with fluid cavities and rutile hairs. This is sufficient to establish the identity of the mineral, which is distinguished also from apatite and early basic plagioclase by its index of refraction.

The periods of crystallisation of the hornblende and the quartz were too widely separated to allow us to suppose that this is a graphic intergrowth due to simultaneous crystallisation. The hornblende had practically ceased to form before the plagioclase felspar had started, and the latter in its turn entirely preceded the quartz. A similar relationship between these two minerals has been described by Romberg,* who compares it with the contact structures described by Salomon† and others. It may, however, be

* Romberg, J. Petrographische Untersuchungen an Diorit, Gabbro, und Amphibolgesteinen. Neues Jahrbuch fur Mineralogie, ix. Beilage Band (1894), p. 307.

† Salomon, W. Ueber einige Einschlüsse metamorpher Gesteine im Tonalit. Neues Jahrbuch fur Mineralogie, vii. Beilage Band (1891), pp. 482, 483.

Salomon, W. Geologische und Petrographische Studien am Monte Aviolo in Italienischen Antheil der Adamellogruppe. Zeits. der deutschen Geol. Gesell., B. 42. (1890), p. 450.

much more probably ascribed to corrosion, as in a case described by Milch in his paper on the Granitic Rocks of the Riesengebirge,* where he discusses the origin of a similar relationship between biotite and quartz. In the Elginshire rocks the biotite has indeed been corroded, but to a much less extent than the hornblende, which is often perfectly honeycombed.

Corrosion of the hornblende occurs only in the presence of biotite, as, in the diorites of Dandaleith and the Cone Rock, where biotite is absent, the hornblende is always compact. Some of the hornblendes in the Netherly diorite are quite unaffected, and those most corroded are usually associated with biotite in such a way as to suggest that by the rapid growth of the latter the magma had been locally enabled to attack the hornblende. Where the two minerals are clustered together there is often between them a narrow seam of quartz, representing the still fluid magma which acted as the medium for a transfer of the molecules from one mineral to the other. The quartz and felspar which fill the cavities are quite full of small crystals of apatite and magnetite, the characteristic enclosures of the hornblende. These are also, it should be remarked, either very few or entirely absent from the normal quartz of the rock. This has been noted as a feature of minerals filling corrosion spaces by Backstrom† and by Milch.‡ That resorption did not begin till a comparatively late period in the consolidation of the rock is shown by the fact that where a crystal was entirely enclosed by biotite it has escaped; where protected only on three sides the liquid magma has eaten its way into the crystal from its exposed surface (Fig. 1). The material filling the cavities is always the latest products of crystallisation, viz., quartz, orthoclase, and very occasionally an acid plagioclase (oligoclase). The developmental history must have been somewhat as follows:—Hornblende preceded biotite, and was followed by plagioclase felspar, though the periods of formation of those three were not absolutely consecutive but to a slight extent overlapped. The magma, now highly acid and rich in alumina and the alkalies (having in fact the composition of a eurite or aplite), corroded the hornblende where exposed to its action, forming biotite partly at its own expense, partly at that of the hornblende.

The formation of biotite from the corrosion of hornblende (and also of pyroxene) by acid magmas, has been described by many writers; among others by Becke,§ Sollas,‖ Holland,¶ Parkinson,**

* Milch, L. Beitrage zur Kenntniss der Granitischen Gesteine des Riesengebirges. Neues Jahrbuch fur Mineralogie, xii. Beilage Band (1899), p. 145.

† Backstrom, H. Ueber fremde Gesteinseinschlusse in einigen skandinavischen Diabasen. Bihang till K. Svenska Vet-Akad. Handlingar, Bd. xvi., Part ii., No. i. Stockholm (1890).

‡ Milch, L. Beitrage zur Kenntniss der Granitischen Gestein des Riesengebirges. Neues Jahrbuch fur Mineralogie, xii. Beilage Band (1899), p. 145.

§ Becke, F. Petrographische Studien am Tonalit der Rieserferner. Tschermak's Min. Petrog. Mittheilungen, Band xiii. (1892), p. 408.

‖ Sollas, W. J. On the Volcanic District of Carlingford and Slieve Gullion, Pt. i. On the Relation of the Granite to the Gabbro of Barnavave, Carlingford. Trans. Royal Irish Academy, Vol. xxx., pp. 477 and 494 (1894).

¶ Holland, T. H. On Augite Diorite with Micropegmatite in Southern India. Quart. Jour. Geol. Soc., Vol. liii., p. 405 (1897).

** Parkinson, John. On an Intrusion of Granite into Diabase at Sorel Point (Northern Jersey). Quart. Jour. Geol. Soc., Vol. lvi., p. 340 (1900).

and Cole.* The spongy nature of the corrosion skeleton is paralleled by the cases described by Backstrom,† Milch,‡ and Sollas. In the granophyre of Barnavave the hornblende, which is largely after pyroxene, is often completely riddled with quartz (Sollas). In the basic modification of the granophyre of Carrock Fell the augite is being replaced by green hornblende and other substances, and is often in graphic intergrowth with felspar (Harker).§

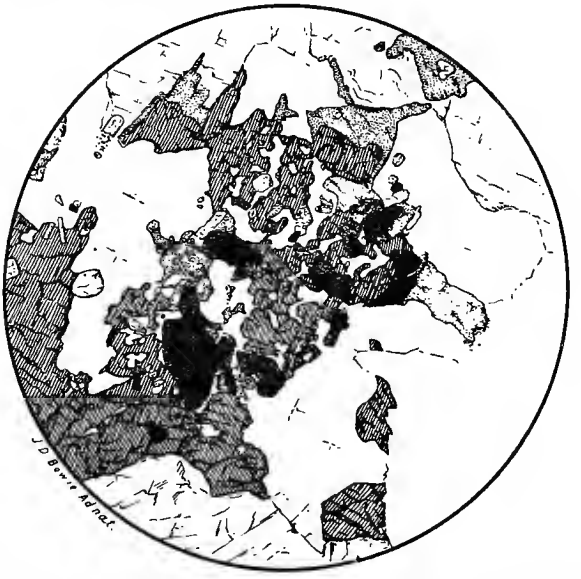

FIG. 1. Corroded Hornblende filled with Quartz. Quartz Diorite, Netherly, Burn of Rothes, Elgin. (Section No. 9550.)

Most of the spongy hornblende belongs to one individual which in polarised light is seen to be repeatedly twinned. It is partly enclosed in biotite (stippled) and plagioclase felspar, and these have protected it from corrosion. Towards the centre of the figure and at the upper border it is in contact with quartz which penetrates it in ramifying processes. These extinguish simultaneously with the external quartz and enclose many small crystals of apatite and magnetite.

There is nothing whatever to indicate that the corroded hornblende crystals in the Netherly diorite are xenocrysts. They have all the appearance of original crystals which have crystallised out from the magma. The intrusive rock has risen through a series of quartzose Moine schists which contain no hornblende or augite, and so far as is known, no igneous masses more basic than the diorite itself. They may in part have resulted from the destruction of pyroxene, but by far the greater number of them show no traces

* Cole, G. A. J. On Metamorphic Rocks in Eastern Tyrone and Southern Donegal. Trans. Roy. Irish Acad., Vol. xxxi., Part xi., p. 431 (1900).

† Backstrom, H. Ueber fremde Gesteinseinschlusse in einigen skandinavischen Diabasen. Bihang till K. Svenska Vet.-Akad. Handlingar, Bd. xvi., Part ii., No. i. Stockholm (1890).

‡ Milch, L. Beitrage zur Kenntniss der Granitischen Gesteine des Riesengebirges. Neues Jahrbuch fur Mineralogie, xii. Beilage Band (1899), p. 145.

§ Harker, A. Carrock Fell: a Study in the Variation of Igneous Rock-Masses Part ii. The Carrock Fell Granophyre. Quart. Jour. Geol. Soc., Vol. li. (1895), p. 125.

of such an origin. Rosenbusch has remarked that the principal pause in the crystallisation of the diorites takes place after the formation of the plagioclase felspars, and before that of the alkali felspars and of the quartz. It is to this period that this action is to be assigned. Examination of a series of sections of rocks of this group has shown that this structure is by no means rare, though not often so well developed as in the diorites under consideration.

The dykes which proceed from the granitic masses and intersect the schists in the vicinity of Craigellachie and Rothes in great numbers, are in most cases of a granitic character and show little variation from the type of the parent mass. They are fine to medium grained granites, not porphyritic, and without any chilled edges. Some are rather basic and rich in biotite and sphene, others more acid and approach aplites in composition.

In the gneisses and schists of the burn of Rothes, veins of a coarse muscovite pegmatite occur. The felspar is oligoclase and an alkali felspar which rarely shows microcline structure. A few small rounded garnets are present. The muscovite is often stained dark red by an infiltration of hæmatite along its cleavage planes. The rocks show effects of shearing. A curious feature of these dykes is the presence of a string of quartz along its centre, indicating that crystallisation proceeded inwards from the margins of the vein. The quartz contains many large fluid cavities with mobile bubbles.

Only one rock of the lamprophyre group has been detected in this area, indicated on the map as camptonite. It forms a thin sill in the quartzites at Aikenway on the Spey, near Mulben. The rock is rather fine grained, dark coloured, with small elongated hornblende prisms, and reddened, decomposed felspar. Under the microscope a greenish-brown hornblende is the most conspicuous mineral, in idiomorphic prisms, not greatly elongated. The transverse section is bounded by the following faces, 110, 010, and 100, the last only occasionally and very small. It is terminated by 001 and $\bar{1}11$. It has the usual prismatic cleavage well developed, and pleochroism :—*a*, pale greenish yellow; *b*, brownish green; *c*, darker green; slightly brown. Twinning on the orthopinakoid is rare. A pale green, almost colourless augite is present also, and like the hornblende mostly free from enclosures. The two minerals are often associated, but apparently not in parallel growth. The pyroxene is fairly abundant, is not usually idiomorphic, and has possibly suffered from corrosion, though traces of the prism and pinakoids are sometimes visible in the transverse section. It is much decomposed and filled with chlorite, serpentine (?), and calcite, but when fresh gives brilliant polarisation colours, and has a high angle of extinction (40° and over). Scattered through the felspar there is much yellow epidote in little grains which do not appear to have resulted from the decomposition of a second generation of ferromagnesian minerals; small hornblendes occur but they have all the characters of the larger crystals, and a perfect gradation in size can be traced, so that the rock is not porphyritic in the proper sense of the term. Felspar in long lath-shaped crystals, somewhat radially disposed, envelops the ferromagnesian minerals and is of later formation, though not entirely, as sometimes a hornblende

surrounds a felspar, to which it forms a narrow border. In longitudinal section such hornblendes are "swallow tailed," with hollow ends filled up with a felspar crystal. Most of the felspar shows polysynthetic twinning, and appears to belong to andesine and allied varieties, but in the thinnest parts of the section it is obvious that orthoclase is present, surrounding the plagioclase, and in places it is dappled like anorthoclase. The latest felspar is intergrown in a rude graphic fashion with a sparing amount of quartz, which forms also an interstitial material between the felspar prisms. The accessory minerals are iron oxides, weathering to leucoxene and limonite, and apatite in numerous long, pointed needles.

This rock is obviously a dioritic lamprophyre, and in several respects, more particularly in the presence of quartz as an undoubtedly primary ingredient, is distinct from the typical camptonites, which are among the most basic of all igneous rocks.* It might perhaps be regarded as a basic Vogesite, but is better assigned to the group of Spessartites which Rosenbusch has established for vogesitic lamprophyres in which plagioclase is the principal felspar. With the lamprophyres (spessartites) of the Spessart as described by Goller it is almost completely identical.†

Dr. Mackie, of Elgin, has prepared an extensive and very interesting series of chemical analyses which include several rocks from this area. They will be found in the Transactions of the Edinburgh Geological Society, Vol. VIII., Part I, 1901. From these we take the liberty of quoting the following (I. to VIII.). For a full discussion of their bearings on many important questions in theoretical geology, the original papers should be consulted.‡

| | I. | II. | III. | IV. |
|---|---|---|---|---|
| $SiO_2$ . . . | 74·75 | 75·39 | 77·18 | 68·01 |
| $TiO_2$ . . . | — | — | — | Tr. |
| $Al_2O_3$ . . | 14·08 | 13·62 | 13·78 | 17·34 |
| $Fe_2O_3$ . . | 1·18 | ·70 | 1·07 | 3·66 |
| FeO . . . | ·85 | — | — | — |
| MuO . . . | Tr. | — | — | — |
| CaO . . . | ·49 | 1·84 | ·12 | 2·06 |
| MnO . . . | ·04 | Tr. | ·05 | ·77 |
| $K_2O$ . . . | 5·39 | 4·39 | 3·27 | 4·41 |
| $Na_2O$ . . . | 3·09 | 2·77 | 3·68 | 2·05 |
| $P_2O_5$ . . . | ·12 | — | ·17 | ·41 |
| Cl . . . | — | ·06 | — | ·069 |
| Loss on ignition . | ·34 | 1·21 | ·63 | ·64 |
| Total . . | 100·33 | 99·92 | 100·01 | 100·249 |

I. Ben Rinnes Granite. II. Granite vein, Craigellachie Bridge. III. Granite vein, Fiddich Bridge. IV. Ruthrie (grey) Granite, Aberlour.

*Flett, J. S. The Trap Dykes of the Orkneys. Trans. Roy. Soc., Edin., Vol. xxxix. (1900).

†Goller, Erw. Die Lamprophyrgänge des sudlichen Vorspessart. Neues Jahrbuch fur Mineralogie, Beilage Band vi. (1889), p. 485.

‡Mackie, W., M.A., M.D. Seventy Chemical Analyses of Rocks (chiefly from the Moray area). Trans. Edin. Geol. Soc., Vol. viii., Pt. i. (1901), p. 33.

On Differences of Composition between the Central and Marginal Portions of Granitic Veins. Trans. Edin. Geol. Soc., Vol. viii. Pt. i., p. 98.

| | V. | VI. | VII. | VIII. |
|---|---|---|---|---|
| $SiO_2$ . . . | 58·44 | 53·22 | 51·78 | 54·09 |
| $TiO_2$ . . . | Tr. | — | ·80 | — |
| $Al_2O_3$ . . | 21·43 | 16·84 | 19·74 | 16·72 |
| $Fe_2O_3$ . . | 6·88 | — | 11·20 | — |
| FeO . . . | ·31 | 9·27 | — | 9·38 |
| MuO . . . | Tr. | — | Tr. | ·52 |
| CaO . . . | 4·84 | 8·53 | 7·17 | 8·35 |
| MgO . . . | 3·66 | 6·48 | 4·52 | 5·58 |
| $K_2O$ . . . | 1·14 | 1·39 | ·99 | ·97 |
| $Na_2O$ . . . | ·59 | 3·54 | 1·76 | 1·23 |
| $P_2O_5$ . . . | ·23 | — | ·07 | ·39 |
| Cl . . . | ·16 | — | ·18 | ·05 |
| Loss on ignition . | 2·01 | ·95 | 1·32 | 2·58 |
| $CO_2$ . . . | ·19 | — | $FeS_2$ ·54 | — |
| Total . . | 99·88 | 100·22 | 100·07 | 99·86 |

V. Netherly Diorite—periphery of boss. VI. Netherly Diorite—nearer centre.
VII. Netherly Diorite—centre of boss. VIII. Diorite, Dandaleith.

## II. The Earlier (Foliated) Igneous Rocks.

The second group of igneous rocks represented in this area is obviously prior to part at least of the earth movements which have affected the region, and this is reflected in their structure. They are more or less foliated and altered in their mineral constitution. The acid rocks are now in the condition of augen gneisses, the basic principally hornblendic schists.

Grey augen gneisses, which have apparently been developed from porphyritic muscovite granites, occur in the immediate vicinity of Keith, and also at localities some miles to the south and north of it. Large elliptical phacoids of pearly white felspar, sometimes showing Carlsbad twinning, lie in a finely gneissose matrix consisting of muscovite, biotite, and granulitic quartz and felspar. Cataclastic structures are very highly developed, the felspar of the phacoids (which is in large part microcline) is much broken and shattered and injected with veins of finely granulitic material.

The basic foliated igneous masses belonging to this earlier series are found principally in the south-east corner of the sheet, and are well exposed in the sections on the Blackwater, a tributary of the Deveron. They are gabbros, epidiorites, hornblende schists and serpentines, but vary in character a good deal, some showing a more complete reconstruction than others in which the original structure of igneous rocks are still well preserved.

Among the less altered types may be instanced the gabbro, one mile north of Blackwater Lodge, at the extreme south margin of the sheet, which consists of brown, turbid schillerised diallage and

basic plagioclase felspar. Flaser structure is visible in the hand specimen, as the rock is crossed by parallel streaks of dark green hornblende. Under the microscope the structure is in places that of a normal gabbro without olivine, but for the most part the diallage is passing into a pale green amphibole which forms masses of fibrous prisms, in the centre of which more or less of the original pyroxene remains. This diallage is often broken, the felspar shows a superinduced twinning due to pressure, and is becoming granulitised. A dark brown original hornblende sometimes surrounds the diallage, but the green amphibole is of new formation, and may be seen to radiate outwards from the diallage, penetrating the surrounding felspar.

A section of a specimen taken along the outcrop of this mass a little further to the north shows that the schillerised diallage is here changed entirely into green hornblende in large, compact masses of irregular outlines, enclosing numerous grains of opaque iron oxide. The felspars are coarsely granulitic, the original structure of the gabbro being obliterated. In this felspar small ragged prisms of hornblende lie scattered. There is a little biotite and epidote, but no pronounced foliation or parallel structure. The rock is an epidiorite.

Associated with this gabbro there is a mass of serpentine. In section it has very much the appearance of having resulted from the decomposition of pyroxene, as the rectangular lattice structure is well marked. The original rock may have been a pyroxenite.

At Craigdorney, further north-east along the same outcrop, there is a diallage peridotite which presents some points of interest. The rock consists principally of olivine and diallage, the former in rounded masses weathering into yellow green serpentine which is covered with a meshwork of dusty magnetite. The pyroxene is almost colourless, with a perfect platy lamination and innumerable minute dark enclosures which render it almost opaque, and are disposed in at least two series. Occasionally a small mass of diallage, with brown, platy schiller enclosures of the usual type, forms a centre surrounded by the paler variety. There is no lustre mottling or poikilitic structure, but the diallage is much broken and bent. Tremolite is abundant in colourless prisms which surround and penetrate the clusters of olivine grains, and pass in winding streams through the broken plates of diallage. It is often free from enclosures, or may be filled with dusty magnetite. Evidently it has been developed at the expense of olivine, or perhaps partly also from diallage. The rock contains no felspar. A very pale yellow, almost colourless chlorite is a rather plentiful ingredient of the rock, and appears to have resulted from the weathering of the diallage.*

A somewhat more advanced stage of metamorphism has been reached by the basic sills on the Blackwater, above Ardwell Bridge. They are represented in the collection of slides by 1788 hornblende

* Patton, H. B. Serpentin und Amphibol Gesteine von Marienbad. Tschermak's Min. Petrog. Mittheil., Vol. ix. (1888), p. 111.

rock, schistose, with large porphyritic hornblendes; 9548 and 9595, hornblende schists with a little epidote and decomposing felspar. The last of these is fine-grained with drawn-out eyes of hornblende resembling phenocrysts, and would seem to have been originally an augite porphyrite. In these rocks no trace of original igneous structures remains, with the exception of these indications of porphyritic structure.

On the Blackwater, 300 yards above the bridge at Ardwell, there is a hornblende schist filled with little oval lenticles of calcite, which readily weather out, giving the rock a pumiceous appearance. The calcite seems to have been present before the production of the foliation, as around the spots of this mineral there is always a border of hornblende and biotite which appear to be pushing inwards, penetrating the calcite, much as the hornblende in sheared gabbros can be seen to spread through the felspar. The calcite forms a mosaic of crystalline grains, with few traces of fracture or deformation. The matrix of this schist consists of a foliated, fine-grained aggregate of hornblende, biotite, and plagioclase felspar, with much magnetite and finely granular epidote. It may have been a fine-grained, vesicular, basic sill, but the appearance of the rock suggests at once the possibility that it is a contemporaneous lava.

## III. Metamorphic Rocks of Sedimentary Origin.

Metamorphic rocks of sedimentary origin occupy by far the largest portion of this sheet. In the north-west there is a large area of quartzose and micaceous schists, with thin flaggy granulitic gneisses (Moine schists). In these, though there can be no doubt of their ultimate nature, all trace of clastic structures has disappeared. An account of the microscopic characters of this group of rocks will be found in the Explanation of Sheet 75, pp. 35 and 36.

At Ballindalloch a zoisite granulite forms a band in this series. The rock is a fine-grained, granulitic gneiss, with a good deal of biotite in small scales rather uniformly dispersed, so that the rock is grey with paler and darker streaks. In this there is a light-coloured band, with well marked lenticular folia of biotite. The microscope shows that the principal components are quartz and felspar in rounded or interlocking grains, mingled with small irregular scales of biotite, which give it a parallel structure. The felspar is partly untwinned orthoclase or albite, but includes also a considerable amount of polysynthetic crystals, which sometimes show two sets of intercrossing lamellæ, and are partly oligoclase, partly more basic varieties. Garnet is present in crystals up to 2 mm. across, and, in addition, zircon, apatite, epidote, zoisite, magnetite, and a reddish, pleochroic sphene.

The zoisite is in lath-shaped crystals, which, while not highly idiomorphic, often show bluntly-pointed terminations and angular cross sections, which are bounded by crystalline faces. The crystals

are from four to ten times as long as broad, have a perfect longitudinal cleavage and numerous transverse fractures. In polarised light they give the usual dark-blue colours, straight extinction, and exhibit longitudinal stripes which recall polysynthetic twinning. A pale yellow, almost colourless epidote is common also in small, irregular grains, often surrounded by zoisite in parallel growth. The zoisite crystals are small, ranging from ·5 by ·12 mm. down to minute granules, the average diameter of the felspar and quartz being ·2 to ·3 mm. In certain bands the zoisite is abundant, in others scanty, and it is often to be remarked that intimately associated with it there is a very small amount of calcite, which elsewhere is practically absent from the rock.

Whether the zoisite is to be attributed to the effects of mechanical shearing on basic plagioclase, or to the contact action of igneous intrusive masses on a calcareous granulite, is not quite clear in this case, as it will be seen that, from its proximity to the Ben Rinnes granite, evidence might be adduced in support of either view. These minerals are by no means common accessories in rocks of this group, but they have been met with in Ross-shire and Inverness-shire by Mr. Gunn, Mr. Horne, and Mr. Grant Wilson, and described by Mr. Teall in the Annual Reports for the years 1897 (p. 41), 1898 (p. 13), and 1899 (p. 40). As will be seen on reference to the descriptions, there is a certain amount of similarity between the specimens from widely separated localities. All are granulites consisting of quartz, felspar, and biotite, with accessory garnet, sphene, zircon, iron ores, rutile, epidote, and zoisite. But the prevalent type in Inverness and Ross-shire contains hornblende, which is often micropoikilitic with enclosures of quartz and felspar, a structure also shown by the zoisite in some cases. Hornblende, however, is absent from the zoisite granulite of Sgurr Mor Fannich (Annual Report, 1898, p. 13). The Ballindalloch rock appears also to be a good deal finer grained than those previously described, in which the zoisites are sometimes 7 to 8 mm. long. But it is clear that as a group those zoisite granulites have a well-defined character; and, indeed, the nature of this rock was recognised by Mr. Hinxman from its appearance in the hand specimen, though the zoisites are much too small to be visible to the naked eye.

In the rocks of the Banffshire series, which occupy the eastern half of this sheet, metamorphism is far less advanced than in the western granulitic schists. The original clastic structures are often to be traced, while in some cases they have suffered little modification. Thus, in the sections on the Blackwater, in the extreme south-east corner of the sheet, bands of grit or greywacke occur containing rounded grains of quartz and of weathered felspar in a dark, fine-grained matrix. There are practically no signs of mechanical strain in the quartz with the exception of a lamellar structure visible between crossed nicols as ill-defined, parallel bands. The matrix consists of fine-grained quartz and brown biotite in small scales, which, from their perfect freshness and the fact that they frequently penetrate the quartz, are of new development. The crystalline

nature of the ground mass, in view of the absence of cataclastic structures, may be reasonably ascribed to contact action by the adjacent intrusive epidiorites.

The section of a quartzose grit from Drummuir shows an essentially similar rock, in which somewhat greater modification has taken place. Although quite a grit or greywacke in the hand specimen, the rock shows under the microscope that the quartz grains have been drawn out and fractured and wisps of a pale mica have been developed, probably from an original felspathic ingredient.

A still further stage of alteration is seen in sections prepared from the gritty bands which occur among the phyllites in the railway cutting at Mulben. In these, original clastic structures can seldom be observed. A fine mosaic of granular quartz, crossed by scales of biotite in parallel series, is the appearance usually presented. The mica penetrates the quartz, passing through it without regard for its boundaries. Reconstruction is fairly complete, for it is rare to find that the quartz shows evidence of mechanical strain or cataclastic fracture.

The silvery micaceous phyllites of this locality consist of muscovite and biotite, intimately mixed, forming wavy parallel folia, often crossed at high angles by an *ausweichungsclivage*. Chlorite is present, and rounded garnets which seem to be weathering into chlorite. The other accessories are rutile, zircon, epidote, tourmaline and magnetite.

The limestones of the Banffshire series have been converted into granular, holocrystalline marbles, rather coarse-grained, and often of a grey colour from the presence of disseminated graphitic dust. They contain occasionally a few scales of a pale yellow, slightly dichroic mica, which is more abundant in certain bands where it is mixed with quartz to form a sort of calc mica schist. The mica may give the rock an ill-defined parallel structure. Occasional rounded grains of quartz are the only common accessory. There are, so far as the sections show, no calc-silicates, and their absence may be due, as Mr. Grant Wilson suggests, to the original purity of the limestone.

The black schist which is so characteristic a member of the Banffshire series may be best described as a dark graphitic phyllite, and in the hand specimen often shows the most minute puckering and *ausweichungsclivage*. It consists of quartz, felspar, muscovite, biotite, and fine graphitic dust; and when coarser-grained passes into a graphitic mica-schist. In addition to the usual accessories of this group of rocks—magnetite, rutile, tourmaline, iron ores, pyrites, and varying amounts of calcite, it contains often little clear, red, rounded garnets, tremolite or actinolite, and chlorite.

The chlorite is practically an essential constituent, being always present in the sections in greater or less amount. In colour, form, and optical properties, it varies a good deal. It is commonly a pale green or greyish-green mineral, with feeble dichroism, the rays vibrating parallel to the cleavage being greyish green, perpendicular to it slightly more yellow (pale yellow green). Pleochroic halos

are frequent around small indeterminable enclosures. These are black (very dark green) for the transverse rays (*a* and *b*). The double refraction is much above that of ordinary chlorite, the polarisation colours being grey of the first order, a little below that of felspar. But the most noticeable peculiarity is the polysynthetic twinning, seen between crossed nicols as light and dark alternating stripes running parallel to the cleavage. The obliquity of extinction in these twin lamellæ ranges up to 12 degs. The mineral is always optically positive, biaxial with a variable axial angle (up to about 40 degs.), and must be assigned to clinochlore. Its enclosures are quartz, zircon, and fine dust of graphite or magnetite.

In this form it usually occurs in streaks, tufts or radiating masses. There is no reason to believe that it is other than a primary constituent of the rock, of which it forms distinct folia alternating with others principally of quartz, or muscovite and biotite (9596). In other sections (9597) from the black-schist series, it forms little tablets with squarish or rectangular sections, taking no part in the foliation of the rock, which they cross obliquely; and it is usually associated with quartz in small, rounded or lenticular spots. The polysynthetic twinning and method of occurrence give it then a great resemblance to ottrelite, from which, however, the lower double refraction and the hardness, which is only about 2, serve best to distinguish it. This appears to be the same mineral as is described by Mr. Teall (Mem., Sheet 75, p. 11) as possibly chloritoid.

What appears to be another variety of chlorite, colourless, or very pale yellow, is a very frequent constituent of the black-schist, both in this sheet and in other parts of the Southern Highlands. It shows the same polysynthetic twinning, oblique extinction, optically positive character, and variable, mostly small, axial angle. The pleochroism of the pale yellow crystals is slight (*c*, pale yellow; *a* and *b*, pale brownish yellow). A colourless or pale yellow ottrelite has been described by Foullon* as a constituent of certain graphitic calc mica schists, but that this is not ottrelite is proved by its softness (H.=2), flexibility, and low specific gravity. By means of a borotungstate solution this was determined to be 2·789; that of the clinochlore already described, 2·81. The specific gravity of Foullon's material was over 3·15. As it is impossible to obtain flakes entirely free from enclosures, these figures can be only approximations. In optical characters it resembles to some extent margarite, a mineral recorded from corundum rocks by Williams† and Tschermak.‡ But of a large number of cleavage flakes examined in convergent light, all were optically positive, while margarite is negative. The double refraction is also too low

* Foullon, Baron von. Ueber die petrographische Beschaffenheit der Krystallinischen Schiefer der untercarbonischen Schichten und einiger älterer Gesteine aus der Gegend von Kaiserberg bei St. Michael ob Leoben. Jahrb. der k. k. Geol., Reichsanst xxxiii., p. 220 (1883).

† Williams, G. H. The Contact Metamorphism produced in the adjoining Mica Schist and Limestones by the Massive Rocks of the Cortlandt Series. Amer. Jour. Sci. (1888), Vol. 36, p. 254.

‡ Tschermak, G. Ueber den Schmirgel von Naxos. Tschermak's Min. Pett. Mittheil Vol. xiv., p. 311 (1895).

for a mica. In many cases in which the two minerals could be accurately compared in this respect, it proved to have always a slightly lower double refraction than quartz; though in vertical sections it invariably gave higher colours than felspar, The multiple twinning is usually obvious, thin plates, not more than ·05 mm. thick, being sometimes composed of as many as ten lamellæ, but others are quite simple; and this explains the irregular behaviour in convergent light. In hot, strong sulphuric acid, the mineral was slowly attacked. These characters indicate that it is a colourless chlorite with positive optical character and oblique extinction, a member of the group of which leuchtenbergite* is the best known example. It generally occurs in small, well-formed plates which lie on the edges of small, rounded or elliptical lenticles of quartz. The basal sections show rarely any tendency to assume hexagonal outlines, but in the crushed powder a parting along a six-rayed pressure figure is often visible, Vertical sections are rectangular or lath shaped, Not infrequently it is in parallel growth with biotite, the two having their basal planes in apposition.

A very frequent accessory in the black-schist is tremolite or actinolite in elongated prisms, the dark colour of which is due to enclosed graphitic matter. In microscopic section, where free from enclosures, the mineral is colourless or pale green. Long, radiating prisms, arranged in feather-like aggregates, are sometimes visible on the surface of the hand specimens (9594, 2091). That the crystals have been developed before the foliation of the schist may sometimes be proved by their fractured condition, little eyes of quartz having been formed in the wake of the broken prisms (9595). In section 2091 the crystals of pale actinolite are filled with dark graphitic matter in wavy parallel lines, and the extinction sweeps over the section in undulations which correspond to the puckering of the lines of enclosures. The crumpling of the folia must be of later origin than the actinolite crystals.

From the abundance of tremolite in the calc-silicate hornfelses, which alternate in thin bands with the black-schist, and the absence or scarcity of carbonates in the black-schist itself when the amphiboles are present, it is probable that they are to be ascribed to the action of contact metamorphism, whether by the earlier or later intrusive igneous rocks, on the calcareous phyllites. The great susceptibility of this series to contact alteration is one of its chief characteristics, and has been noticed in the early chapters of this memoir.

## IV. Effects of Contact Metamorphism.

Effects of contact metamorphism are to be traced in many parts of this area, and owing to the variety of rock types involved, a considerable diversity of products is to be expected. Unfortunately

* Lacroix (Mineralogie de la France et de ses Colonies, T. i., p. 383) has found that leuchtenbergite is common in the limestones of the Pyrenees where altered by contact with ophites and lherzolites.

the exposures of the contact zone around the Ben Rinnes granite are not good, but near Aberlour and Craigellachie the numerous veins which intersect the schists have produced comparatively little alteration. That is, perhaps, mostly due to the resistant nature of these quartzose schists. The schist enclosures in the Ben Rinnes granite (9605) and in the Netherly diorite are baked into a compact biotite hornfels; while at Blue Hill, Aberlour, and at Craigellachie, quartzo-felspathic-schists are indurated and hornfelsed. Dr. Mackie records the presence of sillimanite in the masses affected by the granite veins at the latter locality. In the igneous rock itself flakes of biotite and hornfelsed leaflets of schist may be traced along the margins of the veins, but there is nothing in the way of endomorphic modification, except perhaps the presence of small rounded garnets in the granitic rock. On Hunt Hill, north-west of Aberlour, the granite encloses numerous fragments of quartzite and quartzo-felspathic-schists, the quartzites lustrous and crystalline, while the felspathic quartzites have been to a large extent re-crystallised, with the development of a mosaic structure (the *pflaster-structur*—"pavement structure"—of Salomon*).

At Netherly, on the Burn of Rothes, beside the little wooden footbridge, there is the best exposure of the inner contact zone of the newer granito-dioritic masses to be seen anywhere in this district. The dark coloured, rather coarse-grained diorite is in the form of a sill resting on and partly breaking across the quartzose schists. At several places the actual contact can be inspected. Here, as everywhere in this sheet, these schists vary in character, certain bands being mainly quartzose and felspathic, others richer in muscovite and biotite. The more quartzose become converted into grey, lustrous quartzites, which have a smooth, shining fracture. The more felspathic and micaceous rocks have yielded biotite hornfelses, consisting of quartz, felspar, and a rich brown biotite such as is found in many contact zones. These rocks have lost their schistose structure more or less completely, and may become spotted by the development of biotite in nodular patches. Under the microscope they consist of a mosaic of equidimensional grains (Salomon's pavement structure) but the large conspicuous biotites are poikilitic with enclosures, principally of quartz and felspar.

This type of structure, the spongy contact structure of Salomon,* is still better seen in the andalusite and cordierite hornfelses which alternate with those described. They are dark bluish or grey rocks, turning brown when weathered, in which the schistose structure has nearly entirely disappeared, while the development of biotite in rounded areas gives them a dark spotted appearance. Occasionally a pink band is produced by the presence of garnet.

Under the microscope they prove to consist of essentially the same minerals as the cordierite rocks described by Mr. Teall from the area to the south of this (sheet 75) and from around the Ben Cruachan granite.† Quartz, orthoclase, and plagioclase felspars,

* Salomon, W. Ueber einige Einschlüsse metamorpher Gesteine im Tonalit. Neues Jahrbuch fur Mineralogie, vii. Beilage Band (1891), pp. 482, 483.

† Summary of Progress of the Geological Survey of the United Kingdom for 1898, p. 88.

deep brown biotite, muscovite, cordierite, andalusite, and garnet are the principal ingredients. Zircon, rutile, sagenite in minute networks, a green spinel, sillimanite, and iron oxides are the commonest accessories. The more important minerals are not irregularly scattered through the rock, but are distributed in bands, in each of which one of them predominates, while from the others it may be completely absent. Thus, certain bands are rich in biotite and muscovite, others in quartz and felspar, others in andalusite or garnet or cordierite, the contact minerals of new development being confined to those parts of the rock which had originally the composition necessary for their production. This confirms the view taken by Mr. Teall and by Salomon* that the formation of cordierite contact rocks around a granitic intrusion is

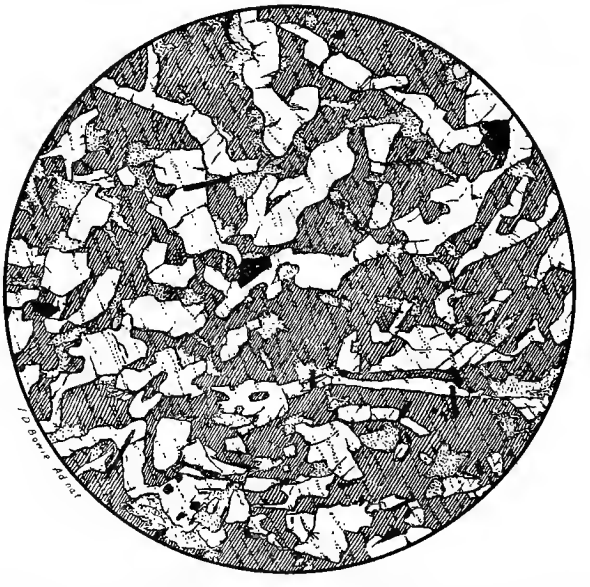

Fig 2. Graphic intergrowth of Quartz and Cordierite (shaded) as seen between crossed Nicols. Cordierite Hornfels ; Netherly, Burn of Rothes, Elgin. (Section No. 9599.)

conditioned by the presence of certain types of schists. The primary foliation thus indicated, is obscured by the new development of poikilitic (spongy) structure, in which the contact minerals form large plates of quite irregular form, as seen in section, filled with enclosures of the other components. In this way occur garnet, biotite, cordierite, and andalusite, and to a less extent muscovite and felspar. The commonest enclosures are quartz, felspar, zircon, iron oxides and biotite. The cordierite in one section (9559) is in graphic intergrowth with the quartz it envelops ; the two minerals

* Salomon, W. Geologische und Petrographische Studien am Monte Aviolo in Italienischen Ant eil der Adamellogruppe. Zeits. der deutschen Geol. Gesell., B. 42 (1890) p. 504.

through interpenetrating one another have each a single position of extinction over a considerable area (*see* Fig. 2).* Mr. Kynaston has described a similar graphic intergrowth of quartz and felspar in the Cheviot andesites as a product of contact alteration.† This points to the mass having been at one time in a plastic or semifused condition. It should be noted that Salomon‡ has described glass enclosures as present in certain contact minerals. At the same time, the preservation of the original foliation, as described above, shows that there was never sufficient liquidity to allow of mixing taking place to any considerable extent. As Mr. Teall remarks, "the cordierite contact rocks have certainly never been in a state of igneous fusion; and yet there has been a sufficient amount of molecular freedom to admit of groupings of the same type as those occurring in molten magmas."§

The minerals of these rocks call for little remark. The cordierite is colourless and not dichroic, except that it shows the usual halos around zircon. It is not filled with streams of sillimanite needles as in the rock of the Black Dog.‖ Sillimanite is, in fact, not easily identified with certainty. Scattered yellowish prisms are abundant in the rock, and may, perhaps, belong to this mineral, but the characteristic divergent aggregates are much less common, though also present. The andalusite is in spongy masses, or streams of little rectangular prisms, colourless, or turning faint pink when the polariser is rotated. The biotite is deep reddish brown, the garnet pale red, and always poikilitic. Rutile occurs in prisms, in networks (sagenite), and intergrown in iron oxides in elongated yellow prisms in the manner described by Hutchings¶ in the ottrelite slate of Tintagel in Cornwall. Quartz and felspar form a mosaic of rounded, closely-fitting grains. The green spinel which is characteristic of the cordierite contact rocks, is present in small rounded octahedra, but is not abundant. The cordierite is mostly very fresh, but in some of the slides it is weathering into a micaceous mineral, and this facilitates its identification.

The black-schists and phyllites of the Banffshire series in many localities furnish minerals which may be regarded as contact products. The tremolite and actinolite they frequently contain have already been discussed in this connection. In the neighbourhood of Ardwell Inn, on the Deveron, chiastolite slates and staurolite and andalusite schists are found in some places in contact with the intrusive epidiorites and other rocks of the earlier igneous series, in such a way as to leave no room for doubt that these

* Lacroix (Mineralogie de la France et de ses Colonies, T. i., p. 521) has recorded the presence of quartz and cordierite in graphic intergrowth in certain rocks from the Pyrenees.

† Kynaston, H. Notes on Contact Metamorphism around the Cheviot Granite. Trans. Edin. Geol. Soc., Vol. viii., Pt. i. (1901), p. 24.

‡ Salomon, W. Ueber einige Einschlüsse metamorpher Gesteine im Tonalit. Neues Jahrbuch fur Mineralogie, vii. Beilage Band (1891), pp. 482, 483.

§ Teall, J. J. H. On the Natural History of Cordierite and its Associates. Proc. Geol. Assoc., Vol. xvi., Pt. 2, p. 72 (1899).

‖ Bonney, T. G., on Bastite-Serpentine and Troctolite in Aberdeenshire, with a Note on the rock of the Black Dog. Geological Magazine, 1885, p. 439.

¶ Hutchings, W. Maynard. On the Occurrence of Ottrelite in the Phyllites of North Cornwall. Geol. Mag. (111), Vol. vi., p. 214 (1889).

minerals are the result of their contact action. Section 9599, andalusite and staurolite schist, from contact with the serpentine on the Blackwater, shows a mica-schist, with muscovite and biotite, large cross twins of staurolite up to $\frac{1}{3}$-inch in length, filled with enclosures of quartz, and crystals of pale, slightly pleochroic andalusite, less numerous, with the same spongy structure. It is to be remarked that the micaceous folia of the rock wind round the staurolites and do not pass through them, a fact which suggests that this mineral was of prior development to the foliation. Some of the staurolites appear broken and shifted, while granulitic quartz has penetrated between the fragments. But the shearing effects of the folding in this region are local and variable, as may be appreciated from the descriptions of the gabbro and epidiorite masses, some of which are highly foliated, others almost massive, or showing only the earlier flaser structures. The grit on the Blackwater, which has already been mentioned, is free from cataclastic structures, and another rock in the same condition is a fine chiastolite slate, which is worthy of a rather more detailed description. It was found on the hill immediately behind the inn at Ardwell.

The matrix of this slate (Fig. 3) consists of biotite in small, deep brown flakes, finely divided quartz, and minute dark grains of magnetite and graphite. It is in that condition generally associated with a fairly advanced thermal alteration, being much coarser-grained and more crystalline than is normal in slaty rocks. An incipient foliation is produced by the parallel disposition of the scales of mica, and by their aggregation into winding parallel bands, which curve round the chiastolite crystals. The rock is spotted, there being paler rounded patches, in which, on the whole, mica is less abundant and the structure more coarsely crystalline. Other spots are due to little rounded nests of biotite and muscovite, and in the centre of these sometimes a small chiastolite is forming. From place to place this matrix varies a good deal in character, both in coarseness of grain and in the relative proportion of its constituents. Scattered through it are small, rounded, almost colourless garnets, and these are sometimes enclosed in the chiastolite crystals.

The crystals of chiastolite in transverse section are cross-shaped, and consist of two arms crossing nearly at right angles. This is due to the imperfect development of the edges of the prism, which are represented by lacunæ bounded by prism faces. In some crystals the notches in the corner are deep, in others quite shallow (*see* Fig. 3). The re-entrant angles are not due to twinning, as the sections have a uniform extinction throughout. In the centre of these crystals there is a dark core such as is usual in chiastolite, lozenge-shaped in section, the edges being parallel to the faces of the prism. It consists of chiastolite, enclosing fine graphitic dust. This material bears no resemblance to the matrix of the slate; it is finer grained, contains little biotite, and is sufficiently transparent to give the optical characters of chiastolite. From the corners of this core, narrow lines of similar character pass outwards to the

notches in the corners of the prism, and in many crystals these lacunæ are being filled up with the same turbid chiastolite, only in this there is more mica, and the size of the enclosures is greater, corresponding with that of the materials of the matrix of the slate. In this way the imperfect edges of the prism are being healed up by a growth of impure material.

Evidently the centres of the prism faces, as was pointed out by Rohrbach in describing similar crystals in a rock from Venezuela,* grow outwards more rapidly than do the edges, which are left

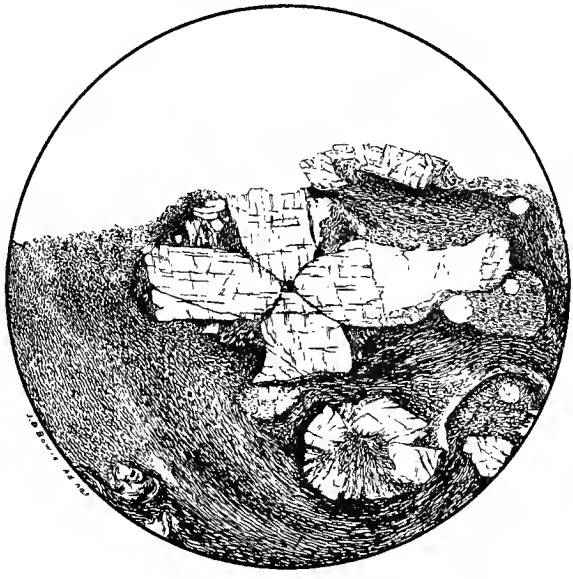

Fig. 3. Chiastolite in Chiastiolite Slate ; Ardwell Inn, Banffshire. (Section No. 9603.)

The crystals show the cross-shaped transverse section, with the imperfect corners being filled in with impure material. The small round clear crystals are garnet ; an irregular mass of quartz is partly enveloped in the chiastolite

behind and form depressions. A pure chiastolite, almost entirely free from enclosures, gathers on the centres of the faces; the re-entrant angles are filled up with impure material. Becke,† who accepts Rohrbach's explanation, compares this method of growth with that of the "hour-glass" augites, in which molecules of slightly different optical properties group themselves on different faces of the crystal. The chiastolite may be said to grow in skeleton form and at a later period to have the interstices of the skeleton filled up. That this is a feature of the whole life history of a crystal is shown by the radiate spokes which pass outwards from the centre to the

* Rohrbach, C. E. M. Ueber die Chiastolith genannte Varietat des Andalusit. Zeits. der deut. Geol. Gesell., Vol. xxxix. (1887), p. 632.

† Becke, F. Ueber Chiastolith. Tschermak's Min. Pet. Mittheil, Vol. xiii. (1892), p. 256.

depressions on the surface. They are the persistent traces of the notches in the corners of the prism. Becke regards the central enclosure as the trace of the terminal faces of the crystal, on which he supposes a turbid chiastolite also to be deposited. Were growth to continue till the skeleton is completely filled up, each corner of the prism would show a rectangular dark spot, like that in the centre, and connected with it by narrow lines, and like it with edges parallel to the surfaces of the crystal; and this type of chiastolite is well known. To this variety of chiastolite Sederholm* has given the name of Maltesite.

Other proofs of contact action by the intrusive sheets in this vicinity, are the dark biotite hornfelses into which the impure shales above Ardwell Bridge have been converted in immediate contact with the epidiorites (hornblende schists).

The calcareous layers intercalated in the black-schists in several places have been altered to calc-silicate-hornfelses, which consist mainly of tremolite or a pale actinolite, often dark with abundant graphite. Sections were prepared from rocks of this group collected at Dufftown and at Tullochallum, on the river Fiddich. They were fine grained, and in addition to the minerals named, one section showed calcite, a pale yellow biotite, epidote, zoisite, quartz (?), and a colourless mineral which was sometimes polysynthetic, most probably plagioclase felspar. That these are products of thermal metamorphism there can be little doubt, though it may not be possible to point to any igneous mass, whether of the older or of the newer series of intrusions, as indisputably the cause.

Away from the immediate vicinity of any exposures of intrusive rocks, minerals which are frequent products of thermal metamorphism occur in many localities scattered over this sheet. While in some cases there may be doubt to what cause there presence is to be ascribed, taken as a whole they indicate a widespread thermal action in this area. It may be interesting to give a list of them and the localities in which they are found.

KYANITE.—Corriehabbie,† Boharm,† Mulben,† Allt Beag† (Glen Rinnes), Burn of Aldernie,† Mortlach,† Botriphnie.†

ANDALUSITE.—Mortlach, Glen Tervie, Shenwell on the Blackwater, Netherly (Burn of Rothes), Botriphnie, Auchentool.†

CORDIERITE.—Netherly (Burn of Rothes).

STAUROLITE.—Near Keith,† Burn of Boharm,† Burn of Aldernie, Auchentool, Shenwell on the Blackwater.

CHIASTOLITE.—Near Keith, Ardwell Inn.

SILLIMANITE.—Netherly, Craigellachie.

ZOISITE.—Ballindalloch (in granulite), Tullochallum (calc-silicate hornfels).

TREMOLITE.—Tullochallum, Dufftown.

GREEN SPINELL.—Netherly.

* Sederholm, J. G. Om Maltesit en Kiastolitartad andalusitvarietet från östra Finland. Geol. Fören. Förhandl., No. 173, B. 18, p. 391, 1896.

† *See* Heddle's "Mineralogy of Scotland."

Of the metamorphic schists, and Banffshire Series also, we are fortunate in possessing a number of recent chemical analyses, for which we are again indebted to Dr. Mackie, of Elgin. The list appended is extracted from his papers in the Transactions of the Edinburgh Geological Society, Vol. viii., Pt. 1901, pp. 33 and 98.

| | I. | II. | III. | IV. | V. | VI. | VII. |
|---|---|---|---|---|---|---|---|
| $SiO_2$ . | 56·67 | 72·48 | 77·37 | 54·01 | 75·10 | 96·51 | 72·64 |
| $TiO_2$ . | 1·45 | — | — | ·89 | — | — | 1·42 |
| $Al_2O_3$ . | 20·25 | 15·86 | 11·22 | 22·86 | 14·23 | 2·02 | 11·61 |
| $Fe_2O_3$ . | 7·01 | 3·25 | 2·92 | — | 3·99 | ·77 | 4·86 |
| FeO . | — | — | — | 7·33 | — | — | — |
| MuO . | ·64 | — | — | Tr. | — | — | ·46 |
| CaO . | 5·04 | 2·21 | 1·40 | 1·11 | ·74 | ·26 | 1·20 |
| MgO . | 1·52 | ·12 | ·46 | 1·91 | 1·08 | ·05 | ·98 |
| $K_2O$ . | 2·54 | 2·51 | 2·94 | 5·12 | 1·64 | ·25 | 2·07 |
| $Na_2O$ . | 3·58 | 3·18 | 2·31 | 2·71 | 1·74 | ·07 | 2·93 |
| $P_2O_5$ . | ·09 | — | — | ·20 | Tr. | — | ·22 |
| Cl . . | ·025 | — | — | — | — | — | ·010 |
| Loss on ignition | 1·47 | ·53 | ·95 | 3·98 | 1·62 | ·46 | 1·35 |
| Total . | 100·285 | 100·14 | 99·57 | 100·12 | 100·14 | 100·39 | 99·75 |

I. Dark Mica-Schist, Rothes Burn. II. Dark Mica-Schist, same locality. III. Quartz Mica-Schist, Rothes Burn. IV. Schist under Granite Vein, Craigellachie Bridge. V. Another specimen, same locality. VI. Quartzite, West of Rothes. VII. Dark Micaceous Slate, Mulben, Banffshire.

J. S. F.

# CHAPTER VIII.

## *OLD RED SANDSTONE.*

The Old Red Sandstone in this sheet covers an area of about 36 square miles along the northern margin of the map. The strata belong to two divisions of that system—Orcadian and Upper—neither of which is typically developed within the limits of the sheet. They are separated from each other by an unconformability, for the members of the Upper Old Red Sandstone not only rest on the basal conglomerates of the Orcadian Series, but pass on to the crystalline schists.

The recent additions to our knowledge of the fossil fishes and plants of the Old Red Sandstone of Scotland, together with the evidence lately obtained regarding the relations of its component members to the newer granite masses of the Highlands, have tended to support the view advocated by Murchison of a three-fold classification of that system into lower, middle, and upper divisions. The evidence based on the fishes and plants has been reviewed by Dr. Traquair and Mr. Kidston respectively, and their statements will be found in the palæontological part of the Appendix to this memoir. In the course of the Geological Survey of Argyllshire, evidence has been recently got to prove that the lavas and breccias in the Black Mount and Royal Forests, associated there with shales yielding *Psilophyton* and therefore on the horizon of the Lower Old Red Sandstone volcanic series of Lorne, have been altered by the intrusion of granite which is a continuation of the Ben Cruachan mass. On the north side of the Grampians, however, pebbles derived from the newer granite masses and their apophyses are found in the basal conglomerates of the Orcadian series. The latter series seems therefore to be of younger date than the lower division south of the Grampians. J. H.

### The Orcadian Series.

The whole of the Old Red conglomerate between the river Lossie and Gallows Hill, forms part of the Middle or Orcadian series. In the sheet to the north (95) this conglomerate dips towards the north and underlies the fish-beds in the burn of Tynet. These beds contain a fish-fauna similar to that of Achanarras (Dr. Traquair), and they are found to the south-west of Tynet in the face of a rock escarpment of one of the higher river terraces situated on the west side of the Spey (95), 650 yards to the north of Dipple.

The "Orcadian Series" in this sheet is composed almost entirely of thick, coarse conglomerates. The beds that form the Old Red Sandstone area, which extends from the river Lossie to some miles to the east of the river Spey, afford unmistakeable evidence that at the time when they were laid down the existing coast-line was sinking at a rate corresponding to that of deposition. On the east side of the river Spey, from Braes Cairn to near Boat-of-Bridge, an unconformable junction separates the Old Red Sandstone from the Highland metamorphic rocks, and the successive beds which compose the newer formation abut in turn against the underlying quartzites and phyllites.

The ground between Braes Cairn and the main road to Fochabers and Keith is occupied by an area of soft brick-red sandstones with a few thin bands of a fine pebbly conglomerate, both with a general dip of 10° to the north. In a small hill-stream to the west of the "Cairn," successive beds of sandstone are seen in turn resting unconformably on the upturned edges of the phyllites. Close to Braewyner and to the west of Pathside, there are excellent exposures of the unconformable junction of the Old Red Sandstone. At the latter spot, resting on phyllites, are red and grey sandstones containing small brecciated fragments of the adjacent metamorphic rocks, and these are, in turn, overlaid by bands of conglomerate which form part of the basal conglomerate to the south. The brecciated fragments in this sandstone are sharp and angular, and exhibit no signs of having been subjected to the action of running water, but appear to have fallen from the ancient sea-cliff, and to have been enclosed in the sandy matrix *in situ*.

The ground to the north of Altash rises rapidly to form the Whiteash Hill, which is entirely composed of the basal conglomerate, well seen in the burn of Fochabers and its tributaries. These side streams, locally known as "Dramlachs," flow through very deep and narrow rock gorges. These have been eroded in the boulder clay and conglomerate, and are often over 100 feet in depth, with almost perpendicular sides only a few feet apart at the bottom of the gullies. The conglomerate is generally fine, of a red or purplish colour, with coarse bands and false-bedded sandy partings. These sandy beds show that the conglomerate is inclined to the north and north-west with an average dip of 8°. The pebbles vary in size from fine gravel up to fragments 3 inches in diameter. The materials out of which it has been formed have been derived from the denudation of the Highland metamorphic series. Pebbles of quartzite compose about two-thirds of the constituents, together with various varieties of mica-schist and gneiss and a few well-rounded pebbles of granite. In addition to these, pebbles of porphyrite frequently occur and appear to have formed part of a contemporaneous volcanic rock. They have generally a dark ground mass, through which are scattered decomposed crystals of felspar. A similar rock is seen in place in the Gollachy Burn, between Port-Gordon and Buckie, in the sheet to the north.

In the burn which drains the south-west slopes of Scotch Hill, and near Culfoldie, the pebbles are almost entirely composed of fine

grey sandstone. Their presence seems to indicate that local denudation of this formation had taken place somewhere within the limits of the Moray Firth basin at the time of the formation of the conglomerate.

For three miles to the south of the Keith road the boundary line of the Old Red Sandstone on the east side of the Spey is only an approximate one, as the ground is partly covered by the large peat moss of Douglassheil and other superficial accumulations. In the Allt Tersie, just below Scotshill farmhouse, there is an excellent exposure of the unconformable junction between the conglomerate and the Mulben phyllites. The conglomerate is very coarse, and for a distance of a hundred yards is seen to rest upon a very irregular and uneven surface of phyllite-schist with quartzose bands. Between this exposure and the foot of the burn, and also in the Spey section at Boat-of-Bridge, both the schists and the quartzites are stained red, indicating that the Old Red Sandstone beds as originally laid down, extended considerably farther to the south.

The boundary line of this formation crosses the Spey valley a little to the north of Orton junction, then winds round the Gerrack Moss, and turning to the south a little to the east of Findlay's Seat descends into the valley of the Spey a short distance to the north of the Greens of Rothes, where low cliffs of conglomerate are seen in close proximity to flaggy quartzites. This portion of the boundary line is very indefinite, Findlay's Seat being thickly clad with drift and timber.

In the Red Burn, near Aultonside, the steep banks are composed of red crumbling conglomerate, dipping N. 10 E., and in the upper branches of this stream there are numerous exposures of deep red and purple conglomerate with yellow sandy patches. Over the district of the Tiendland no rock appears at the surface; but farther to the north-west, the stream which rises south of Humbrack gives a very good section as far as Braehead. It shows a red and mottled purple conglomerate in which the stones are well rounded, and reach as much as a foot in diameter.

Between Rothes and Coleburns a powerful fault forms the south-west boundary of the Old Red Sandstone formation. This dislocation is never actually seen between these two points, but appears to follow the west side of the Glen of Rothes. That such a fault must exist is proved by the fact that the Old Red Sandstone beds in the railway section below Littlehaugh are smashed and brecciated, and often inclined at high angles to the north, while in their immediate vicinity metamorphic schists are seen in a similar broken condition. At the foot of the glen a small stream that rises below the farm of Smallburn affords a good section of the conglomerate. The beds dip N. 8°, and appear to be intersected by several small faults. The stones are mostly well rounded with a smooth surface, are larger at the top of the section than at the bottom, and appear to have been derived from the gneiss and quartzites of the adjacent metamorphic rocks.

The upper portion of the Glen of Rothes is very flat, and is covered with alluvium and peat, but on its steep eastern slopes

between Birchfield and Coleburns there are numerous rock exposures showing bands of purple and red conglomerate, which are either lying flat or gently inclined to the north. The fault which traverses the Glen of Rothes must either die out or pass into the Old Red Sandstone to the north of Coleburns. If this fault continues to the north it must, in all probability, form the boundary line between the upper and middle divisions between Cockmuir and Culbackhillock, but there is no evidence on the ground in support of this view.

Between Coleburns and Gedloch the conglomerate now occupies an area which may have formed a small bay in the coast-line during this period of deposition. On the south-side of the hollow, locally known as the "Slogg," below Gedloch, steep cliffs of a remarkably hard compact conglomerate, with a basal breccia, are opposed to equally steep cliffs of metamorphic rock. From this point to the river Lossie the Old Red Sandstone occupies the lower slopes by Wardend and Shougle. At the foot of the Gedloch Burn red and mottled conglomerate and banded breccia, with thin partings of red sandstone, are seen resting unconformably on hard pink quartzites. That the rock in the district around Thomshill is Old Red conglomerate is inferred from the contents of the drift and the presence of numerous conglomerate boulders which are scattered over the surface, and also the exposure of a small patch of conglomerate to the south of Thomshill. At the foot of the steep slope which lies between the Hillhead wood and the river Lossie there are several good rock exposures, exhibiting deep-red and purple conglomerate, varying from fine to coarse, with well-rounded stones.

Outliers of Orcadian Series.—In this sheet the "Orcadian" division of the Old Red Sandstone when it was first deposited, must have extended very much further to the south than its present limits. This is proved by the numerous outliers which are found scattered all over the map, from the vicinity of the river Lossie to the Lower Cabrach.

Between the river Lossie and the head of Glen Rothes there are two areas of conglomerate and breccia around Middleton and Hangingfold. That the conglomerate at these two localities had at one time been continuous with the main body to the north, is proved by the reddening of the intervening rocks.

On the east side of the Spey four outliers of the "Orcadian" series have been mapped. The largest one is situated to the south of the Hill of Towie, in a flat-bottomed, wooded valley, through which flows one of the head tributaries of the river Isla. The rock exposed along the bank of this stream is a deep-red fine conglomerate, with bands of gritty and pebbly sandstone. At Dufftown, the western pier of the railway viaduct across the river Fiddich is founded upon a coarse, red, brecciated conglomerate, and this small area may extend a short distance up the valley towards Little Tulloch. Near the railway summit between Dufftown and Drummuir there is a patch of conglomerate too small to be shown on the one-inch map. It is seen in the head of a small burn which runs down from the Scaut Hill and close to the railway. J. S. G. W.

In the extreme southern portion of the area under description, two small outliers of the "Orcadian" or middle division of the Old Red Sandstone rest unconformably upon the schists and quartzite of the Banffshire series.

The more westerly of these is found immediately east of Craighead Inn, at the head of Glen Tervie, south of Ben Rinnes, and occupies an area about a third of a mile in length along both sides of the Tervie Burn. The rocks are exposed at several points along the main stream and its tributaries, and consist of coarse, tumultuously-arranged breccia or conglomerate, made up of large sub-angular and rounded blocks of quartzite and mica-schist, the former largely preponderating. The conglomerate closely resembles that which occurs along the western and southern limits of the Tomintoul outlier, with which this isolated patch was no doubt at one time connected.

The extreme northern extremity of the Cabrach outlier, a description of which will be found in the explanation of sheet 75, also falls within the limits of this map, crossing its southern margin a mile to the east of the river Deveron. The area is a very small one, and the exposures of grey or red incoherent sandstone are very scanty. The only point of interest is the occurence of a bed of contemporaneous lava, similar to that which is associated with the Quarry Hill Sandstone near Rhynie, in Aberdeenshire. It is a dark purple amygdaloidal rock, that may be described as an altered andesite. L. W. H.

## Upper Old Red Sandstone.

This division, which is largely developed in the Elgin district to the north, only occupies a few square miles in the map. In the north-west corner of the sheet there is a narrow, irregularly-shaped stripe of the upper beds. In an old quarry near Lochaber about 15 feet of reddish-brown, hard, thick-bedded sandstone has been wrought. This sandstone contains fragments of quartzite and mica-schist similar to those of the metamorphic series immediately to the south. Wherever the rock is exposed, the presence of a conglomerate breccia indicates deposition in a bay of the ancient coast-line between Laurenceton and Drum. From this farm to the point below Rafford where this formation passes out of the sheet, the boundary line has been drawn along the foot of the hard feature produced by the underlying metamorphic rocks.

To the south-east of Tulloch and near the Black Burn, the colour of the drift and the presence of some blocks of red and grey sandstone suggested the possibility of a concealed outlier of Upper Old Red Sandstone. In 1880 a small trial opening was made, and the rock was reached at a depth of five feet, very much jointed and somewhat broken. This sandstone is rather hard, coarse grained, and varies in colour from grey to light pink. It contains a few yellow clay galls, and the beds appear to be horizontal.

A considerable area of these upper strata is found in the valley of the Lossie between the Hills of Mulundy and The Wangie, and it is

very probable that the same beds lie beneath the large alluvial haugh of Dallas between these two hills. In a small stream which flows down the hillside above the Free Church of Dallas, there are several exposures of decomposing conglomerate. A similar conglomerate is to be seen in the river Lossie immediately below the village, and red sandstone with green clay galls and conglomerate in the burn at Auchness. The rock at each of these three localities in all probability represents the basal beds of the Upper Old Red Sandstone series. In a quarry to the west of Dallas Lodge, white, yellow, and reddish thick-bedded sandstones containing clay galls are seen dipping to the north-west. In another quarry beside Hatton, the face shows 40 feet of thick bedded yellow and white sandstone with a gentle inclination to the west. Several miles lower down, on the left side of the river Lossie, and at the edge of the stream alluvium where it touches the 300-feet contour line, there is a small patch of sandstone about 12 feet in length, resting on quartzite.

To the north-east of Rosehill there is a small area of conglomerate and sandstone. The former is extremely hard and very different from the conglomerate of Glen Rothes and the Spey. It is composed of sub-angular and rounded pieces of gneiss, quartzite and quartz. The matrix is exceedingly hard, and in some places almost a quartzite. On the south side of this conglomerate there is a small patch of a fine white sandstone which contains fish-remains. Although the actual junction between the conglomerate and the sandstone is not exposed, the former is doubtless the basal portion of the latter.

A narrow tongue of Upper Old Red Sandstone extends along the north side of the Black Burn from Pluscarden Abbey to the northern edge of this sheet. To the north of the Abbey the sandstones are hard, coarse, and false-bedded, and contain pebbles of quartzite. The quarry on the north side of the road near the bridge of Torrieston has been opened in fine yellowish and white sandstones. These are thick bedded, the yellow sandstone is very friable, and both present a very marked difference to the hard quartzose sandstones found higher up the hill and at the back of the Abbey.

Three hundred yards to the south of Westerton House, Blackburn, a small patch of Old Red Sandstone is seen near hard, grey metamorphic flags. To the east of Whitetree, in the same district, there is a similar deposit, and in the absence of direct evidence to the contrary these two small outliers are regarded as belonging to the upper division of the Old Red Sandstone.

The triangular area of the upper beds indicated on the map to the east of the river Lossie, and around Longmorn Station, contains the well-known fossiliferous locality of "Scaat Craig." In the centre of the small glen through which flows the Longmorn Burn, and 366 yards to the south-west of Whitewreath, there rises a rounded knoll of fine red and yellow crumbling conglomerate, locally known as the "Scaat Craig." The bedding of the rock is quite distinct, and is inclined at an angle of 8° in the direction of N. 20 W. The section is now very much obscured by the crumbling nature of the rock, the growth of plants along its face, and by rubbish shot over from

the cultivated ground above. Fossil fish-remains are got at the "Craig," but they are not very numerous. They are most abundant about 300 yards higher up in the bed of the stream and opposite to the underway railway bridge, in a soft, yellow and red sandstone. The fossils are very brittle and the greatest care is required to preserve them, as they have often to be removed from the rock in small fragments. Dr. Traquair has kindly supplied the following list of fossils obtained from this well-known locality:—

Psammosteus pustulatus. *Traquair.*
Cosmacanthus Malcolmsoni. *Agassiz.*
Bothriolepis major. *Agassiz.*
Conchodus ostreiformis. *M'Coy.*
Holoptychius nobilissimus. *Agassiz,*
,, giganteus. *Agassiz.*
,, decoratus. *Eichwald.*
Polyplocodus sp.

For 200 yards to the south of the railway bridge, the beds are inclined to N. 30 W. at a low angle. This section is composed of bands of fine conglomerate, with coarse deep red, and light and dark yellow sandstones. Some of the sandstones are ripple-marked, and the contrasting colours of the different bands produce a very fine effect. At the end of this section there is a gap of about 200 yards before the deep red conglomerate of the "Orcadian" group appears. J. S. G. W.

Mr. Taylor, Lhanbryde, has furnished a note of the fossils collected by him in recent years from the following localities in the Upper Old Red Sandstone:—(1) from quarry near Burgie House, in the north-west corner of the sheet, *Psammosteus Taylori*, *Bothriolepis major*; (2) from Hatton Quarry, near Dallas, *Holoptychius nobilissimus*; (3) from Pluscarden Abbey Quarry, *Holoptychius nobilissimus*; (4) Torrieston Quarry, about half-a-mile east of Pluscarden, *Holoptychius nobilissimus* and *Bothriolepis* fragment. Mr. Taylor's determinations have been confirmed by Dr. Traquair.

The horizons in the Upper Old Red Sandstone to which these fossils probably belong will be discussed in the memoir of the Elgin district (sheet 95). J. H.

# CHAPTER IX.

## *GLACIAL DRIFT AND RECENT DEPOSITS.*

### Glacial Drifts.

During the period of maximum glaciation the region under description appears to have been under the influence of two principal ice-movements. The centre of dispersion in the one case lay to the west and north-west, from which the ice moved south-eastwards over the hilly country between the Lossie and the Spey. The mountain ranges of Cairngorm and the Monadhliath in the south-west formed another great centre, whence the ice-sheet descended on to the plains of Moray.

Few striated or ice-worn surfaces are to be seen. In the western portion of the area the rocks are mostly concealed beneath superficial deposits, and where exposed are, from their nature and rapid weathering, ill-adapted to retain ice-markings. Striæ pointing east and south-east are seen near Rafford, in the north-west corner of the map, and seem to be due to the earlier glaciation; but the few other striæ found along the courses of the Spey and Deveron belong to the later valley glaciation, and follow the trend of the river valleys. Such later ice-markings are seen at Carron (E. 20 N.), and Tomhead near Arndilly (north-west) in Strathspey; at Craigdorney on the Deveron (north-east); and at Braehead, south of Keith (N. 40 E.). The distribution of boulders and nature of the drift would seem to indicate that the ice-sheets coming from the north and south-west were confluent along the north side of the Spey valley as far, perhaps, as Aberlour. To the north of that point the Moray ice became dominant, causing a deflection of the Strathspey ice-sheet to the east; while the contents of the drift over the ground north of a line drawn from Craigellachie to Keith show that it was derived from areas lying to the west and north-west.

Erratic Blocks.—Boulders of a coarse pink granite with large crystals of orthoclase, and also containing microcline, are found in great numbers on the hill slopes and summits between Dallas and the Spey, and extend eastward as far as the seaward slopes of the Mannoch Hill. They have evidently been derived from a mass of similar granite which covers a considerable area on the Findhorn between Coulmony and Dulsie Bridge. The granite mass of Moy, still further to the west, is the probable source of blocks of grey biotite-granite which are scattered freely over the same region, and have been traced south-eastwards beyond Knockando and Phones in Strathspey. L. W. H.

Further confirmation of the ice-carry from a centre of dispersion lying to the north and north-west, is found in the blocks of conglomerate and sandstone distributed over the northern part of the area.

Numerous large boulders of the peculiar conglomerate-breccia of Stonewells, north-east of Elgin, are found considerably to the south-east of that locality; two erratic blocks—the one of deep red sandstone, the other yellow with green galls, both of which have been derived from the upper Old Red Sandstone strata of the Findhorn valley—are seen at the Meikle Cairn, half-a-mile west of Breachry, Dallas; and similar evidence of the south-easterly movement is afforded by the occurrence at Clackmarras and Fochabers Junction of boulders of conglomerate, granite, and the blue cherty rock of Stotfield and Elgin. On the further side of the Spey, an easterly carry along the northern margin of this area is indicated by the presence, ¾-mile east of Mulben Station, of boulders of red sandstone similar to that of Stotfield Links; and of blocks of conglomerate still further to the east in the direction of Keith. J. S. G. W.

Dr. Mackie, of Elgin, was the first to point out a local dispersion of boulders of the Netherly diorite over the area between the burn of Rothes and Ben Rinnes.* Blocks of this characteristic rock have been traced southwards across the Spey at Wester Elchies as far as Tom-na-Bat and the slopes of Ben Rinnes. These may have been dropped in their present position by a marginal lobe of ice flowing from the large glacier to the north through the hollow that lies to the east of the Hunt Hill down to the Spey, at a time when the lower ground had been left bare by the retreat of the Strathspey glacier.

Boulder Clay.—This deposit is well developed over the greater part of the area, and especially on the higher hill-slopes to the north-west of the Spey valley, where the ravines cut by the head-waters of the streams flowing into the Spey and Lossie show the boulder clay to be of great thickness.

It varies in character with the nature of the underlying rocks. Over the area occupied by the quartz-schists and flagstones it is a somewhat incoherent, yellow, sandy clay, but along the outcrop of the black-schists and limestones it becomes dark in colour and very argillaceous; while over the areas occupied by the Old Red Sandstone strata, and in the region lying immediately to the south and south-east of them, it is red in colour and full of fragments of these sedimentary rocks. Interstratified sands and gravels are not common, but may be seen at Drumnagrain, one mile south-south-east of Ballindalloch Station. The stones imbedded in the boulder clay are mostly sub-angular blocks of local origin, but in the western part of the area there are also many rounded boulders of granite, probably derived from masses lying to the north and north-west.

The present course of the Allt Arder, from the Bridge of Cally to its junction with the Spey, affords an interesting section of the deposits filling up a pre-glacial valley. The stream is now flowing

*Trans. Edin. Geol. Soc., Vol. VIII.

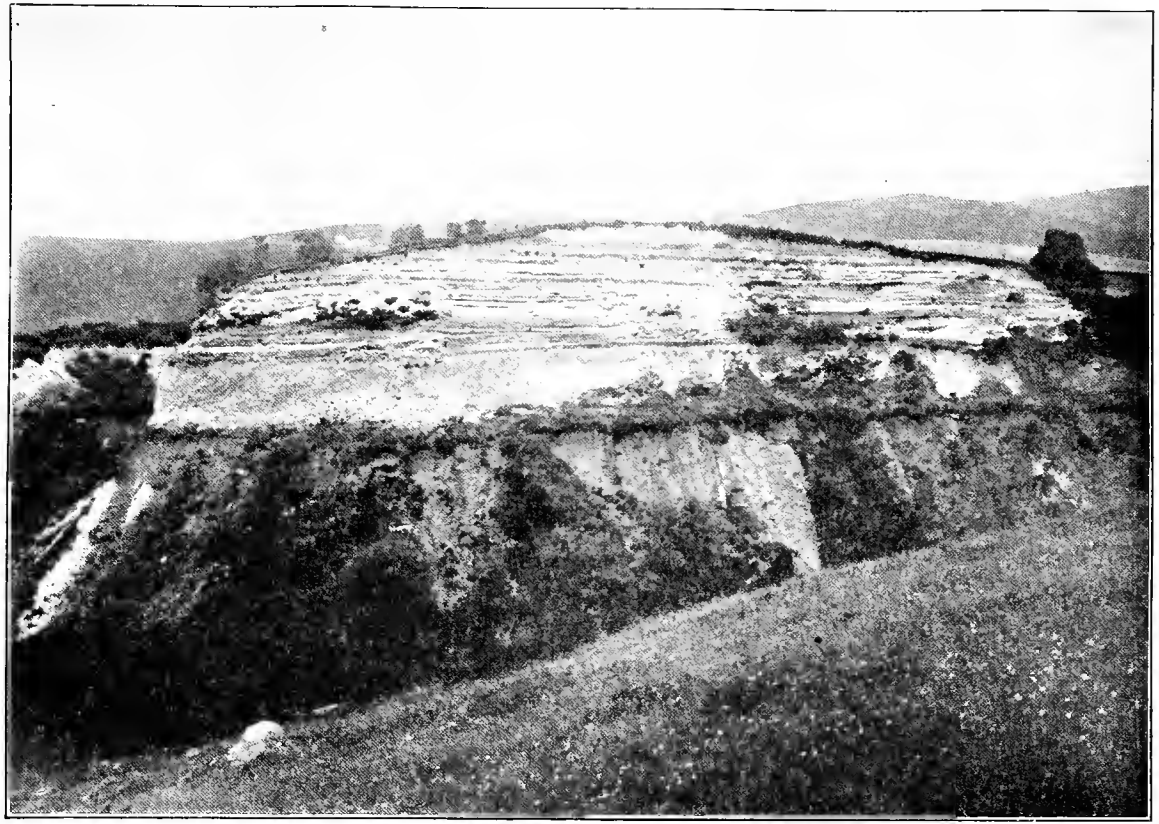

PLATE II.

Pre-Glacial Valley—Allt Arder, Knockando.
Fluvio-Glacial Sands and Gravels resting on Boulder Clay.

along the extreme northern side of the ancient valley, and has for its left-hand bank the original rocky wall of the glen. The southern or right-hand bank gives a clean-cut section of from 100 to 140 feet of fluvial and glacial deposits. The upper portion consists of 20–35 feet of laminated sand and sandy clay, showing oblique and current-bedding, and with occasional bands of pebbles near the base. This is succeeded by 100–140 feet of sandy boulder-clay, containing large angular blocks of quartzite and rounded granite boulders. (Plate II.) L. W. H.

With the exception of a few bare hill-tops, the whole of the ground to the west of the Spey and north of Knockando is covered with superficial drift deposits.

Red boulder-clay, largely made up of materials derived from the Old Red Sandstone to the north-west, covers the slopes of the Monaughty Hill. A portion of the Eildon Hill is clear of drift, but the long ridge that lies between the Black Burn and the river Lossie is again completely drift-covered. Thick deposits of boulder-clay occupy the ground on the south side of this river. The scars cut by the Lennox Burn show as much as 135 feet of stony brown boulder-clay, sometimes slightly laminated, and near the head of the burn from 20 to 60 feet of a greyish or yellow clay is exposed. The Mannoch Hills are deeply swathed in similar deposits, which to the west of this point seem to reach an even greater thickness; 100 feet of gravelly and sandy drift being seen at the head of the Allt Arder, and nearly 200 feet at the Loch of the Cowlatt. Numerous sections cut by the burn of Rothes show that the yellowish-brown boulder-clay which fills the lower part of the glen must have a thickness of at least 150 feet.

The right-hand bank of the river Spey, nearly opposite the village of Rothes, is formed by a cliff, 200 feet in height, of boulder-clay capped with sand and gravel. The lowest part of the section displays a deep-red, very compact, boulder-clay, containing large striated boulders. To this succeeds a considerable thickness of compact greyish-brown clay with reddish patches and lenticular bands of false-bedded sand and gravel. Mid-way up the cliff, and apparently resting unconformably on this boulder-clay, there follows a great thickness of regularly-bedded sand and gravel, forming part of the high-level alluvial terrace which extends from near Aikenway to the Wood of Arndilly. (Plate III.)

The distribution and character of the boulder-clay in the vicinity of Rothes affords further evidence of the south-easterly movement of the ice over this region. No red boulder-clay is found west of the Glen of Rothes, and the reddened deposits only begin to appear at various distances up to a mile to the east of the Old Red Sandstone boundary. The ground between the Wood of Dundurcas and Findlay's Seat is occupied by schistose rocks, but is covered with compact red boulder-clay which must have come from the north-west. Red boulder-clay is also spread over the low ground at the foot of Ben Aigan, and is seen in the burn in Arndilly wood not far from the top of the hill.

The lower part of the Aultderg Burn, near Fochabers, affords a

very fine example of a pre-glacial valley in the course of being re-excavated by the present stream. The phenomena of erosion seen at this locality are very interesting, and are described later on in this chapter.

The conglomerate area of the Scotch and Gallows Hills is mostly covered with a gravelly drift deposit, but the south-easterly movement of the ice has filled the valley of the Forgie Burn with deep-red drift containing blocks of red sandstone identical with the rock in place between Braes Cairn and Aulthash. A good drift section is afforded by the burn to the north of Herrick's Moss, showing red boulder-clay passing upwards into dark-brown clay capped with sand and gravel. Another good section of compact reddish-brown clay with polished and striated boulders is seen at Rosarie, 2½-miles west of Keith. An analysis of the fragments contained in the clay showed that 68 per cent. were quartzite; 20 per cent. gneiss and mica-schist; 4 per cent. phyllites; 4 per cent. granite; and 4 per cent. Old Red Sandstone.

To the north-east of the granite area of Ben Rinnes the drift is largely composed of granite waste, while to the south of Keith the country is covered with a stiff dark-grey and brown boulder-clay; facts which indicate that this part of the area lies outside the influence of the Moray ice-sheet, and has been overspread with ice coming from the south-west. The valleys between Dufftown, Corsemaul, and the southern margin of the map are more or less thickly covered with boulder-clay of a similar character, which reaches a considerable depth in Glen Rinnes, and at Lynemore attains a thickness of 100 feet. Its local character varies with the nature of the underlying rocks, but it is usually a dark stiff clay, varying in colour between reddish-brown and grey. J. S. G. W.

Sands and Gravels.—A considerable extent of sands and gravels of fluvio-glacial origin covers the low ground around Rafford in the north-west of the map, and stretches southwards as far as Bothies and Briach. These deposits are distributed over the area either as flat plains of gravel, or in the form of small kamiform ridges and hillocks. In the Granary Burn at Rafford the stratified sands and gravels rest upon reddish-brown boulder-clay. On the north side of the Hill of Mulundy the gravels merge into a series of high-level terraces on both sides of the valley of the Blackburn. These terraces are carved out of the boulder-clay slopes, and are in some cases covered with sand and shingle. They are somewhat irregular in disposition and extent; the longest have a gentle inclination to the west contrary to the fall of the present river-valley, and the highest of them reaches an elevation of a little above 500 feet. A similar series of terraces is seen on both sides of the river Lossie for two miles to the south of Dallas, the highest of which almost reaches 800 feet, while the general inclination is in this case down the valley.

A large area immediately to the south is occupied by sand and gravel deposits, kamiform or possibly morainic in character, that lie thickly around the Moss of Bednawinny, and extend to the head of Glen Lossie, sweeping over the moorlands to the north-west as far

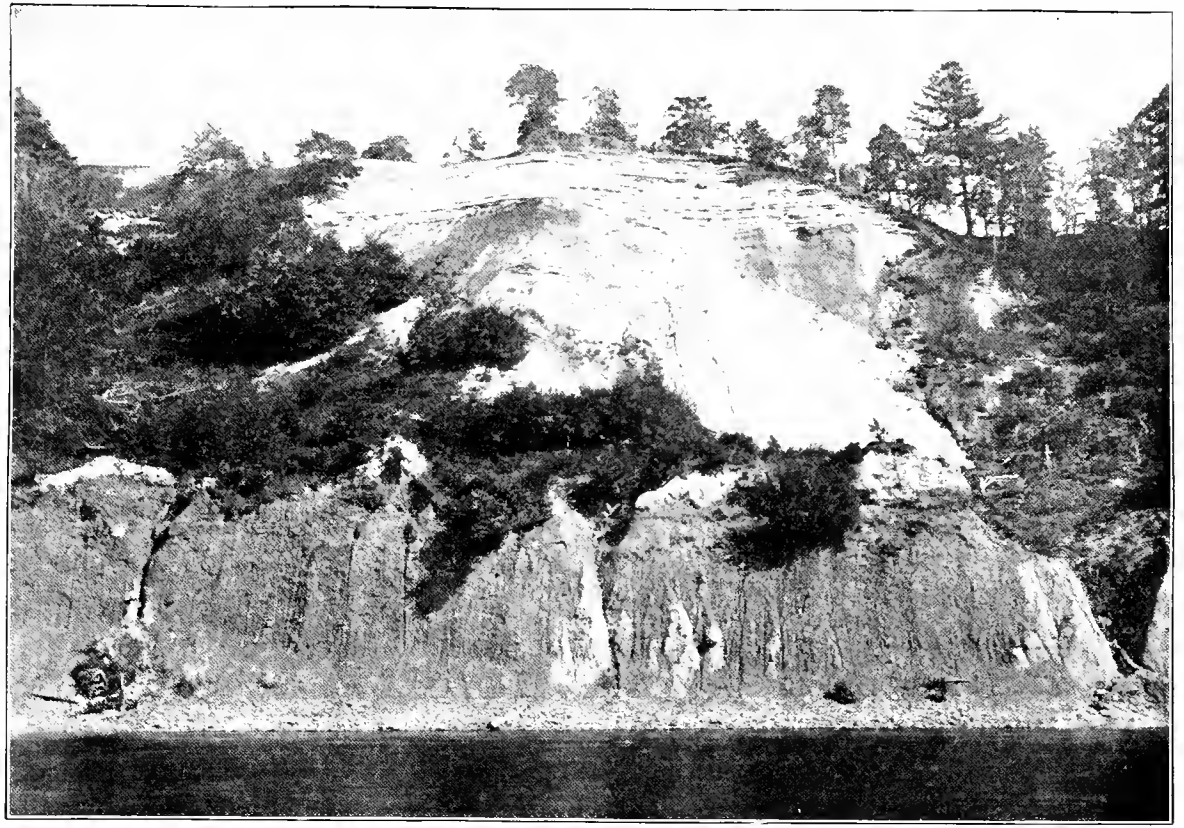

PLATE III.

Sands and Gravels resting on Red Boulder Clay.
Cliff above River Spey, opposite Rothes.

as Rochuln. The stream in Glen Lossie has cut deeply into these mounds at several points, showing the thickness of the deposit of well-rolled fragments to be at least 100 feet. A scar, 200 feet high on the hillside, a short distance east of the Loch of Dallas, shows morainic drift resting upon thick sand, and the alluvial flat to the north of the same loch is overlooked by morainic mounds at least 200 feet in height. A few scattered gravel mounds are also grouped round the farm of Whiterashes in the valley of the Burn of Corrhatnich.

The alluvial flat referred to in the last paragraph is locally known as Loch-na-Braan, and marks the site of a loch which has been drained by the lowering of the drift barrier at its eastern extremity. The thick alluvial deposits laid down in this loch by the hill burns have subsequently been denuded by the stream which now flows through the flat, and has cut three distinct terraces out of the fine sandy silt that fills the hollow.

A large number of sloping broken terraces, with surfaces covered with false-bedded sand and gravel, are carved out of the red stony boulder-clay which clothes the sides of the valley of the Blackburn above and below Westerton House. As far as Crossley they have a gentle inclination down the valley, but below this point they merge into a broad flat plain of sand and shingle, which stretches eastwards to the Lossie. Between the Kellas in Glen Lossie and the hill-slopes to the east of the head of Glen Rothes, there is a further development of these denuded sand and gravel terraces resting upon boulder-clay. To the north they pass into a series of hillocks of sand and shingle, which cover the ground between Paddock Hall and Shougle and extend north-east as far as Blackhills House, while similar deposits occupy the low ground round Orbliston Junction, reaching as far south as Inchberry. A well-marked flat terrace extends for about a mile along the western slope of the Glen of Rothes just below the 600-foot contour-line, between the Glen Burn and Birchfield. It has been cut out of the boulder-clay, and is covered with sand and shingle. There are several other terraces at lower elevations around the village of Rothes which are probably more truly fluvial in their origin, and have to do with an earlier phase in the history of the river Spey.

J. S. G. W.; L. W. H.

In the Glen of Mulben there is another large accumulation of fluvio-glacial sand with bands of gravel, which frequently attains a thickness of at least 100 feet. On the south side of the glen it forms a well-marked terrace, which extends from Sheriffhaugh to Mulben Station, and has a general inclination of 1 in 150 towards the river Spey. The same terrace can be traced, in a denuded and fragmentary form, along the eastern side of the Spey valley under the woods of Ordiequish and Slorach as far as the mouth of the Fochabers Burn.

In the deep ravine at the foot of the Aultderg Burn, which falls into the Spey above Burnside of Dipple, gravel rests upon boulder-clay, which in turns covers the conglomerate below. The height of the bank of the ravine below the farmhouse of Aultderg is exactly

100 feet, made up of nearly equal thicknesses of gravel, boulder-clay, and conglomerate. The surface water rushing down the steep slope of the Ordiequish Hill pours over the edge of the ravine, and has carved out of these soft and incoherent materials a remarkable assemblage of circular steep-sided pinnacles or earth pillars. (Plate I., Frontispiece.) These pillars are invariably capped with a thick covering of tough heathery herbage, and it is to this turf capping that their origin and subsequent preservation is due. The herbage on the slope above the ravine is of unequal thickness, and the surface water as it streams over the edge of the chasm flows round the thicker tussocks and isolates them from the surrounding turf. The portions bared of their grassy covering are rapidly eroded, with the result that the protected portions finally stand out as isolated pyramids, each with its capping of turf. These pillars can be seen in every stage of detachment and isolation from the bank behind, and in those where erosion has proceeded furthest, the gravel and boulder-clay rest upon a base of conglomerate. The wind acting upon the upper sandy layers often undermines the grassy cap until it falls, and the unprotected pillar wastes rapidly away. J. S. G. W.

The laminated sands described as capping the boulder-clay in the Allt Arder section, form part of a deposit of fluvio-glacial sands and gravels that occur at several points along the valley of the Spey. Above Blacksboat and Mains of Kirdells they cover a considerable area on the hill side, presenting a rolling surface of alternate ridge and hollow that merges along its lower margin into the higher alluvial terraces of the Spey. Further traces of the terraced fluvio-glacial deposits are seen along the valley of Knockando Burn between Tomdow and Priestfield. The steep bank on the south side of the stream immediately below Knockando Church, gives a section of 75 feet of fine white sand. On the further side of the same burn, below the Cardow Schoolhouse, a wide and well-marked terrace extends eastwards towards Knockando House. It is composed mostly of finely laminated clayey sand resting upon boulder-clay, and seems along its northern margin to mark the position of a small glacial lake occupying a hollow in the drift. A section in a roadside quarry near Cardow shows great disturbance in the beds of fine sandy silt and clay. They are tilted up at high angles, sometimes nearly vertical, and often violently contorted. The longer axes of the stones that are scattered through the sand are always parallel to the bedding planes in whatever position these may be. The phenomena suggest the action of masses of ice grounding in shallow water. L. W. H.

Brick-Clay.—At Craigellachie Brickfield the clay at present wrought is a light-brown, laminated, glacial silt, with horizontal bedding, and contains thin layers of fine sand or very small gravel, with occasional pebbles up to 2 inches in diameter. This deposit of clay is about 18–20 feet thick. It marks the site of what was once a glacial lochan, and occupies a shallow depression in the drift, about half-a-mile in length. At one portion of the section, false-bedded glacial silt, sand, and gravel are exposed, and these seem to indicate the presence of floating ice. J. S. G. W.

MORAINES.—There are few localities in this region where any regular assemblage of moraines such as mark the track of a local glacier can be observed, though isolated morainic mounds of gravelly drift, often stratified, are seen in various places along the Spey valley.

Such mounds occur at Fanmore and Croftindacker, a short distance west and north-west of Ballindalloch, and on the hillside above Culfoichmore, seven miles higher up the river; while a considerable area in the higher part of the valley of the Allt Breac, in the south-west corner of the map, is covered with morainic drift resting upon boulder-clay. The disposition of the well-formed moraines throughout this hollow indicates a movement of the ice from the north or north-west.

A small morainic mound, almost entirely made up of well-rounded fragments of quartzite, schist, and granite, lies on the water-parting of Creag-an-Tarmachain, between the Spey and the Avon, at a height of 2100 feet. It is difficult to account for the position of this moraine, but the materials may have been deposited by infra-glacial water in a hollow of the ice-sheet that enveloped the Cromdale Hills.

Traces of the local glaciation of the Conval Hills are seen in the corrie on the north side of the Little Conval, two miles west of Dufftown, where a fine specimen of a terminal moraine crosses the mouth of the corrie, and has been cut through in two places by the small stream that has its source on the slope of the hill. These sections enclose large blocks of the Conval granite, and a mass of the same rock rests on the summit of the moraine at its western end. There are further indications of smaller terminal and lateral moraines, both above and below the large moraine described above. L. W. H.

## RECENT DEPOSITS.

FRESHWATER ALLUVIUM.—The largest stretches of alluvium are found along the courses of the Spey, the Lossie, and the Black Burn. Below Pluscarden Abbey the Black Burn meanders through two wide haughs of fine sandy alluvium that were at one time marshes, but have been drained by diverting the stream for several miles into a deep artificial channel. A considerable stretch of alluvium is also found at Bethelem, to the south of Dallas, and is due to a change in the course of the river Lossie, which at one time flowed through the well-marked channel south of Ballachraggan, but now passes to the north of that farm. The village of Dallas is situated on the low delta laid down by the Lossie at the head of the lake that once covered the Haugh of Dallas. This extensive alluvial flat is formed of fine sand and shingle; a portion of it is cultivated, the rest being covered with peat. In the region around Kellas, the Lossie has eroded the thick glacial deposits that fill this river basin, producing a fine series of terraces. These terraces lie below those of fluvio-glacial origin, the highest of them being 62 feet above the present level of the stream. J. S. G. W.

The alluvial terraces that show the successive levels of the flood-plain of the Spey are well marked along the whole course of the river through this sheet.

Between Ballindalloch and Carron, as many as four, five, and six of these terraces can often be distinguished on either side of the river. The highest of these sometimes merges into, and is difficult to separate from, the fluvio-glacial deposits which in places flank the sides of the valley—as between Blacksboat and Knockando. The high-level terraces seen on either side of the Glen of Rothes can be traced more or less continuously by Rothes and Blackhall into the Spey valley, and may be correlated with the 500-feet terraces at Phones and Culquoich, higher up the river, near Knockando. They indicate an earlier course of the Spey through the Glen of Rothes, referred to in Chapter II. Similar high-level alluvial deposits are continued up the valley of the Avon, and are well seen between Ballindalloch and Drumin, where the old castle stands upon a fragment of a higher terrace. The materials at the lowest levels are coarse and often torrential in character, but become finer upwards, and pass, in the highest terraces, into fine sand and silt. This points to a progressive increase in the gradient and consequent velocity of the stream as it cut down through the deposit of an earlier waste-filled basin to the rock floor over which it is now flowing in this portion of its course. L. W. H.

Between Dandaleith and Aikenway Castle there is a considerable stretch of flat alluvial land, the lower part of which is locally known as the Haugh of Rothes. This alluvial stretch lies immediately above the constriction of the valley at the Pass of Sourden, and forms a basin that before the lowering of this rock-barrier may have been occupied by the waters of a lake of considerable size. Northwards from Boat of Bridge to the edge of the map, the Spey has laid down a broad stretch of terraced alluvium—that at Fochabers measures as much as $2\frac{3}{4}$ miles in extent from east to west. A pit-section by the roadside $\frac{1}{4}$ mile north of Inchberry, in the highest but one of these river terraces, shows an alternating series of fine and coarse gravels, fine sand, and clay bands.

As the majority of the streams on the east side of the Spey run through narrow valleys with a rapid fall, there are few extensive alluvial deposits in this part of the area. A broad belt of peat-covered alluvium extends between Mulben and Newmill. The greater part of this area was in all probability laid down when the burn of Auchlunkart flowed eastwards into the Isla. It has since been beheaded by the Mulben Burn, and its waters now flow westwards to the Spey. Narrow stretches of alluvium occupy the bottom of the valleys of the Fiddich, Dullan Water, Deveron, and Isla. J. S. G. W.

Peat.—Basin peat is very generally distributed all over the map, and in the area between the Lossie and the Spey there are some very large and deep peat-mosses. The largest moss of this area is that of Bednawinny, near Dallas, which is about one square mile in extent. In the past these mosses were the chief source of supply

for the fuel used in the district, and they are now in many cases extensively wrought to supply the local distilleries. At the Kettles and the surrounding peat mosses large roots and stumps of *Pinus Scoticus* are found at the bottom of these bogs. The Douglasshiel and Gow Moss supplies Keith with a portion of its fuel, and in the Lower Cabrach the peat moss between Craigwatch and the Brown Hill is very deep.

In addition to the basin peat, a large tract of country lying on the watershed between the Spey and the Lossie is covered with hill peat of varying thickness, and between Dufftown and the south-east corner of the sheet a similar covering envelops the hill-tops and ridges. J. S. G. W.

On the western slopes of Ben Rinnes and in Glen Tervie there are several peat mosses, most of which are worked for fuel. None of these is of very great extent; the largest are found in the Drum of Carron, on the eastern slope of Carnacay, and at the head of Glen Tervie, near the farm of Tomachclaven. A large peat moss appears along the western margin of the map at the foot of the Larig Hill, and peat is also dug at various points along the valley of the Allt Breac below Auchnagallin.

The probable exhaustion at no very distant date of the more accessible areas of basin peat, renders the hill-peat, that covers such wide areas in this region, of some economic importance, this fuel being so largely used in the numerous distilleries of Banffshire and Elgin. L. W. H.

# CHAPTER X.

## *ECONOMIC PRODUCTS.*

The principal rocks of economic value in the district are the limestones of the Banffshire series. The two principal lime-works in this portion of the county are situated at Blackhillock, near Keith, and at Parkmore and Tininver, Dufftown. There are several small openings in Morinsh and along the outcrop of the limestone in Glen Rinnes, also in Glen Fiddich, Glenmarkie, Corsemaul, Lower Towie, Douglasbrae, and Handslach. At Keith, operations are carried on by the Blackhillock Lime Company, Limited, and the annual output of lime is from six thousand to seven thousand tons per annum. The limestone rock in the quarry is of a very high quality, and a sample has been analysed by J. Falconer King, City Analyst, Edinburgh, with the following results:—

| | |
|---|---|
| Carbonate of lime | 96·70 |
| Carbonate of magnesia | 2·70 |
| Sulphuric acid | traces |
| Iron oxide and alumina | 0·15 |
| Water - | 0·20 |
| Silica | 0·68 |
| | 100·43 |

The lime manufactured by this company is to a large extent used for building and plastering work, while less than one-fourth of the total annual output is utilised by the district farmers for agricultural purposes. In addition to the local requirements, this company supplies lime to the wide district between Keith, Inverness, and Aberdeen, and it also consigns by rail to Wick, Thurso, Kyle of Lochalsh and Ballater.

The Parkmore and Tininver lime-works are the property of Mr. Kemp, Keith, and have been carried on by him for many years. The Parkmore works are situated on the east side of the railway viaduct which crosses the river Fiddich to the north of Dufftown, and the kilns and lime stores are connected with the Great North of Scotland Railway by suitable sidings. The Tininver quarry is close to the river Fiddich, below Dufftown. In both these quarries the quality of the rock is excellent, and they are both working the same zone of limestone. Their joint annual output of marketable lime varies from nine to ten thousand tons per annum. Its quality is known in the trade as "a first class Scotch lime."

The lime produced at these works is chiefly used by builders and plasterers, and in a lesser degree for agricultural and gas purifying

purposes. It is consigned to all the districts served by the Great North of Scotland and Highland Railways between Aberdeen and Caithness.

At these joint works eight kilns of the "Clamp" type are constantly employed. When the Parkmore quarry was first opened out, continuous burning kilns were erected. These were similar to those at present in use all over the Carboniferous Limestone districts of the North of England. After a few years' trial these kilns were abandoned and the present type adopted. This change was rendered necessary, partly on account of the requirements of the North of Scotland lime trade and also the difficulty of getting the proper class of fuel necessary for their most economical working.

Analysis of limestone from Tininver Quarry, Dufftown, by J. Falconer King, City Analyst, Edinburgh:—

| | |
|---|---|
| *Lime | 54·43 |
| Magnesia | 1·05 |
| Iron oxide | ·35 |
| Carbonic acid | 43·15 |
| Sulphuric anhydride | trace |
| Organic matter | trace |
| Water | ·08 |
| Insoluble matter | 1·00 |
| | 100·06 |

This limestone will, when burned, form a lime well suited for building, agricultural, or gas-purifying purposes.

(Signed) J. Falconer King.

Analysis of limestone from Braehead Quarry, Keith, by J. Falconer King:—

| | |
|---|---|
| Carbonate of lime | 94·41 |
| „ „ magnesia | 1·72 |
| „ „ iron | trace |
| Lime as sulphate, silicate, etc. | 1·17 |
| Sulphuric acid | ·12 |
| Organic matter and loss | ·44 |
| Moisture | ·06 |
| Silica and insoluble matter | 2·08 |
| | 100·00 |

[Communicated by Mr. James Kemp, Keith, with permission to publish.]

The Upper Old Red Sandstone affords a good freestone, which has long been quarried at Dallas and Pluscarden. A rougher stone of local use is obtained from the lower strata near Fochabers.

The slaty phyllites have been wrought for roofing-slate at Newmill, Mulben, and Tarrymount, but the large quarry at the last-

* Equal to carbonate of lime, 97·20 per cent.

named locality is now abandoned. The black schists have also been extensively quarried on the western slope of the Scalp Hill near Auchindoun Castle and to the north-east of the Hill of Mackalea. Granite and gneiss are quarried for local building purposes at Ruthrie and on the Blue Hill near Aberlour; but dressed stone for lintels and ashlar work is imported from the Elgin district.

Brick Clay.—A considerable manufacture of bricks, tiles, and drain-pipes is carried on at Craigellachie, where terra-cotta ware is also made from the finer parts of the glacial clay.

J. S. G. W.

### Roads, Highways, and Road Metal.

With the exception of the three small areas of Elginshire and the narrow strip of Aberdeenshire along the eastern edge of the map, all the roads and highways on the east side of the river Spey in this sheet are included within the second or Keith district of the county of Banff.* These roads are classed as I., II., III. They have, along with their bridges, been much improved within the past ten or twelve years, and are now throughout the whole district in a very fair and passable condition. Three years ago a steam-roller and plant were purchased by the County Council, and in the parishes where there is traction engine and other heavy traffic the former unsatisfactory condition of these roads has been immensely improved by rolling. The road metal used in the different districts is very diversified in character. This is partly due to the cost of carriage for any considerable distance from the good quarries, and also to the initial expense which would be incurred in providing means of access to places where suitable rock is situated at some distance from a public highway.

* Under the Local Government (Scotland) Act 1889.

## Table Showing Localities and Class of Metal used in the Road Districts, Upper Banffshire—Sheet 85.

From information supplied by Mr. Robert Davidson, Road Surveyor.

| Name of District. | Locality. | Class of Metal. | Notes. |
|---|---|---|---|
| Inveravon, - | Hill above Blairfindy Lodge. | Hard Slate. | |
| | Tombae. | Quartzite. | |
| | Tombrechachie. | Quartzite. | |
| | Hill of Craggan. | Blue Whinstone. | Fine hard quality for road metal. |
| | Tervieside. | Limestone. | |
| | Bed of River Avon. | Various water-worn stones. | |
| | Ballindalloch. | Land Stones and Gravel. | |
| | At different centres. | "Heathen" Boulders. | |
| | Morinsh. | Limestone. | |
| Aberlour, - | Ruthrie. | Granite. | |
| | Above Ryehilloch, Blue Hill. | Granite. | |
| | Bridge of Fiddich. | Granite and Quartzite mixed. | |
| | Loop. | Gravel Pits. | Good Quality. |
| | Eringarrow | Gravel Pits. | Good Quality. |
| | Farm of Hatton. | Gravel Pits. | Good Quality. |
| | Buchromb. | Gravel Pits. | Good Quality. |
| | River Spey, Bed of. | Various water-worn stones. | |
| | At different centres. | Land stones. | |
| Mortlach, - | Tininver Quarry, Dufftown. | Limestone. | |
| | Richmond Quarry, Dufftown. | Limestone. | |
| | Bogbuie. | Quartzite. | |
| | Little Tulloch. | Old Red Sandstone Conglomerate | |
| | Parkmore. | Limestone. | |
| | Lochpark. | Limestone. | |
| | Westerton. | Gravel. | |
| | River Fiddich, Bed of. | Various water-worn stones. | |
| | At different centres. | Land stones. | |
| Glenrinnes, - | Bridge of Lettoch. | Quartzite. | Fine quality for road metal purposes. |
| | Glack Harness. | Granite. | |
| | Rinaitin. | Limestone. | |
| | At different centres. | Land stones. | |
| Cabrach, | Ardwell. | Gabbro | |
| | Bridge of Ardgallie. | Serpentine. | |
| | Glack of Balloch. | Quartzite. | |
| | River Deveron, Bed of. | Various water-worn stones. | |
| | River Deveron, Bed of. | Gravel. | |
| | At different centres. | Land stones. | |
| Botriphnie, | Loch Park. | Limestone. | |
| | Burn of Towiemore. | Limestone. | |
| | Above Drummuir Castle | Quartzite. | |
| | Merchants Croft. | Quartzite. | Decomposed. |
| | Mains of Davidston. | Mica-schist | |
| | Edintore. | Black-schist. | |
| | Pitlurg. | Mica-schist. | |
| | Pitlurg. | Gravel. | |
| | At different centres. | Land stones. | |
| Boharm, | Tauchers Mill. | White Quartzite. | Fine quality for road purposes. Good quarry. |
| | Auchroish Wood. | White Quartzite. | Do. do. do. |
| | Brae above Popine. | White Quartzite. | |
| | Knockandhu. | Gravel. | |
| | Ferranderran. | Gravel. | |
| Keith, - | Black Hillock. | Limestone. | |
| | Rosarie. | Quartzite. | |
| | Blackhill Wood. | Quartzite. | |
| | Above Newmill. | Hard Slaty Phyllites. | |
| | Loanhead. | Hard Slaty Phyllites. | |
| | At different centres. | Land stones. | |
| | Keith. | Augen-gneiss. | |

## Tabular Statement of Road Metal used in the County of Elgin—Sheet 85.

From information supplied by Mr. Alexander Hogg, C.E., County Road Surveyor.

| Parish. | Locality. | Class of Metal. | Remarks. |
|---|---|---|---|
| Bellie, - | From Fochabers towards Keith. | Stream stones. | Fair good quality. Taken from Fochabers Burn. |
| | Fochabers. | Stream and field stones. | From River Spey and heaps carted off land. Fair good quality. |
| | Tynet. | Stream stones. | From Fochabers Burn and other streams. Fair good quality. |
| Speymouth, - | Dipple. | Do. and field stones. | From River Spey and heaps carted off land. Fair good quality. |
| Rothes, - | Orton. | Do., River Spey. | Fair good quality. |
| | Rothes Police Borough Crofts Quarry. | Blue grey quartz-schists | Bottom of quarry good quality; veins of Barytes. |
| | Dandaleith. | Stream stones, R. Spey. | Fair good quality. |
| | Birchfield. | Water-worn stones and strong pit gravel. | Pits N.E. of Birchfield; good rock could be got to west. |
| Elgin, - | Pluscarden. | Stream and pit stones. | Of fair quality; from glacil deposits; good rock to west of Abbey. |
| Kinloss South, | Lawrenceton Quarry. | Hard Quartzo-felspathic gneiss with small granite veins. | Very superior rock for road metal; the best in the county. |
| Forres - | Wester New Forres. | Do. do. do. | Do. do. do. |
| Rafford - | Briach to Rafford from Lawrenceton and Wester New Forres. | Do. do. do. | Do. do. do. |
| | Other parts of Parish. | Water-worn and land stones. | Good quality. |
| Dallas, - | The whole Parish. | Do. do. do. | Do. |
| Birnie, - | The whole Parish. | Do. do. do. | Do. Good rock available to the E. of Shougle. |
| Knockando, - | Easter Elchies Quarry. | Decomposing granite. | Good quality. |
| | Do. do. | Water-worn and land stones. | Do. |
| | Quarry near Carron Road Station. | Granite, close-grained. | Rather soft. |
| | Carron. | Water-worn and land stones. | Good quality. |
| | Archiestown. | Do. do. do. | Do. |
| | Cardow. | Do. do. do. | Do. |
| | Kirdells. | Do. do. do. | Do. |
| | Blacksboat. | Do. do. do. | Do. |
| Inverallan and Advie, - | The whole Parish. | Do. do. do. | Do. |

### Mineral Wells

Chalybeate springs are of frequent occurrence along the outcrop of the ferruginous black-schists. Amongst the best known of these are the Priest's Well near Dufftown; a well at Tulloch, west of Kininvie; and a very strong iron spring which rises in the middle of a peat moss west of Brown Hill in the Lower Cabrach, and has a great local reputation for its medicinal qualities. The water of the burn below Tulloch is also strongly impregnated with alum derived from the decomposition of the iron pyrites in the black schist.

### Iron.

A thin vein of ironstone was at one time wrought on the western base of Ben Aigan, near Arndilly. J. S. G. W.

# APPENDIX.

## PART I.

### PALÆONTOLOGICAL.

NOTE ON THE FOSSIL FISHES OF THE OLD RED SANDSTONE OF SCOTLAND BY DR. TRAQUAIR, F.R.S.

Mr. Horne having asked me to furnish a brief statement regarding our knowledge of the distribution of fossil fishes in the Scottish Old Red Sandstone, I submit the following notes, which give, in fact, the substance of a paper read by me at the meeting of the British Association at Glasgow in September, 1901.

There are three distinct fish-faunæ in the rocks designated "Old Red Sandstone" in Scottish geology. The first is that of the Lower Old Red Sandstone of the central valley of Scotland, typically developed in Forfarshire; its characteristic fishes being species of *Cephalaspis* and *Pteraspis*, as well as Acanthodians of the genera *Climatius*, *Parexus*, *Euthacanthus*, *Ischnacanthus*, and *Mesacanthus*. This fish-fauna is closely allied to that of the Lower Old Red Sandstone of the West of England, which is again linked with those of the Lower Devonian of Spitzbergen, of Podolia, and of Campbelltown in Canada. It differs, however, from that of the Lower Devonian (Corniferous Limestone) of the United States markedly, in the absence from the latter of the characteristic Pteraspidians and Cephalaspidians, nor does the "Corniferous" show any Acanthodians unless *Machæracanthus* be one. It must be remembered, however, that the Corniferous Limestone is of purely marine origin, having been formed under conditions very different from those under which the Lower Old Red of Forfarshire or the Lower Devonian of Canada were deposited.

The second great Scottish Old Red fish-fauna is that of the Orcadian series, which lies to the north of the Grampians, and this fauna is strikingly different from that of the Forfarshire beds. Only two genera and not a single species are common to both. The occurrence near Thurso of species belonging to the Forfarshire Acanthodian *Parexus recurvus*, Agass, has been mentioned by Sir A. Geikie on the authority of the late Mr. C. W. Peach, but there must be a mistake of identification here, for I have gone over all the specimens of Caithness fish-remains, collected by Mr. Peach, which are in the British Museum, in the Museum of Practical Geology, and in the Edinburgh Museum of Science and Art, without finding a trace of *Parexus*, nor have I seen it in any other collection of fossils from the Orcadian beds. *Parexus recurvus* does, however, occur in the Lower Old Red Sandstone of Herefordshire.

Not only are the Forfarshire and Orcadian fish-faunæ distinct, but their respective "facies" seem to point in different directions. The

Pteraspidæ and Cephalaspidæ are also characteristic Upper Silurian families, as in the West of England and elsewhere. On the other hand, the Orcadian fish-fauna, characterised by Asterolepidæ, (*Pterichthys*, *Microbrachius*), Acanthodidæ (*Cheiracanthus*, *Diplacanthus*), Osteolepidæ (*Osteolepis*, *Diplopterus*, *Thursius*), Rhizodontidæ (*Gyroptychius*, *Tristichopterus*), Holoptychiidæ (*Glyptolepis*), Ctenodontidæ (*Dipterus*) Coccosteidæ (*Coccosteus*, *Homosteus*) Palæoniscidæ (*Cheirolepis*), is, as already remarked by Mr. J. W. Evans, more allied to that of the Upper Old Red, to which it is linked, we may say, by the set of fishes found in the Upper Devonian of Scaumenac Bay in Canada. Of the two genera which are common to the Orcadian and Forfarshire beds, namely *Cephalaspis* and *Mesacanthus*, both also occur in these Canadian Upper Devonian strata, but it must be noted that *Cephalaspis*, so characteristic a Lower Devonian genus, is known from the Orcadian and Scaumenac Bay strata only by a single unique specimen in each case, namely, *C. magnifica*, Traq., and *C. laticeps*, Traq., respectively. It may also be added that *Coccosteus*, though not occurring in Forfarshire, is, like *Cephalaspis*, a genus which goes through the entire formation, being found not only in the Orcadian series, but also in the Lower Devonian of Germany (Hunsrückschiefer) and the United States (Corniferous) as well as in the Upper Devonian of Canada, and the Upper Old Red of Scotland.

Nor does the Orcadian fish-fauna present any greater affinity to any of the Lower Devonian fish-faunæ of Europe or America than it does to those of Forfarshire or Herefordshire. Scanty, however, as is the fish-material collected from the Middle Devonian of the Eifel, it is interesting to note the occurrence there of a well marked species of *Pterichthys* (*Pt. Rhenanus*, Beyrich), and of a species referred to *Osteolepis* by Professor von Koenen, both being prominent Orcadian genera.

The third great fish-fauna is that of the Upper Old Red Sandstone, characterised by *Psammosteus*, *Asterolepis*, *Bothriolepis*, *Phyllolepis*, *Glyptopomus*, *Sauripterus*, *Holoptychius*, and *Phaneropleuron*, which place this series of rocks on the same general horizon as the Upper Devonian of the North-west of Russia, the Famennien of Belgium, and the Catskill of the United States—the fish-remains of the Shetland beds, however, pointing to a position corresponding to that of the Chemung group (Upper Devonian) of the Western Continent. *Bothriolepis* and *Holoptychius* are the most prominent genera of the Upper Old Red, and it is interesting to observe that, though the fish-fauna of the Upper Devonian of Scaumenac Bay has many points of affinity with that of the Orcadian series, the only Asterolepid present is a *Bothriolepis* (*B. Canadensis*, Whiteaves).

The statement by the late Sir Frederick M'Coy (Report on Palæontology in Ann. Rep. of Secretary for Mines, Victoria, 1889) as to the occurrence at Mansfield, in Australia, of a *Pteraspis*, and of fishes specially allied to *Cephalaspis*, *Diplacanthus*, and *Cheirolepis* in the same beds with Palæoniscidæ of Carboniferous type is clearly founded on erroneous determinations. The whole collection on which this Report was based has just been forwarded to Dr. Smith Woodward for description, and I have his permission to state that, having together carefully looked over all the specimens, we found no trace of any Pteraspidian or Cephalaspidian, or, indeed, of anything else characteristically Devonian. The *facies* of the fish-fauna represented in this collection is unmistakably *Carboniferous*.

R. H. TRAQUAIR.

LIST OF THE FOSSIL FISHES OCCURRING AT TYNET BURN, IN THE ORCADIAN SERIES, BY DR. R. H. TRAQUAIR, F.R.S.

*Pterichthys Milleri*, Agass.
,, *productus* ,,
,, *oblongus* ,,
*Cheiracanthus Murchisoni*, Agass.
,, *latus*, Egert.
*Diplacanthus striatus*, Agass.
*Osteolepis macrolepidotus*, Agass.
*Diplopterus Agassizii*, Traill.
*Gyroptychius microlepidotus* (Agass.).
*Glyptolepis leptopterus*, Agass.
*Dipterus Valenciennesii*, Sedgw. and Murch.
*Coccosteus decipiens*, Agass.
*Cheirolepis Trailli*, Agass.

Species occurring at Gamrie, and elsewhere on the Moray Firth, but which I have not seen from Tynet Burn as yet:—

*Diplacanthus longispinus*, Agass.
,, *tenuistriatus*, Traq.

R. H. T.

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NOTE ON THE FOSSIL PLANTS OF THE OLD RED SANDSTONE OF SCOTLAND BY MR. R. KIDSTON, F.R.S.

The Fossil Plants of the Old Red Sandstone of Scotland show a clearly defined three-fold division of this formation. The flora is not numerous in true species, for many of the species which have been made have been founded on material far too imperfect to be of any scientific value.

Records of the occurrence of *Lepidodendron*, *Calamites*, etc., in the Old Red Sandstone of Scotland, must, I am afraid, be cancelled. In some cases I have seen the specimens on which the record was made, and even with the most liberal interpretation of these genera, it is impossible to admit the specimens into the genera in which they had been placed.

The upper division is characterized by the occurrence of *Archæopteris hibernica*, Forbes sp., and contains an altogether distinct flora from that of the two underlying divisions.

The Orcadian division contains a very common plant, which I recorded as *Psilophyton robustius*, Dawson. Better and more perfect specimens have shown me that I was in error, and that the plant I had believed to be *Psilophyton robustius*, Dawson, was the lower portion of the plant, whose upper part was the *Ptilophyton Thomsoni*, Dawson, whose stem is the *Caulopteris Peachii* of Salter. This species is very common in the Caithness flags, and is entirely absent from the Perthshire and Forfar Old Red strata. The so-called *Lycopodites Milleri*, Salter, and a few other species are also peculiar to the Caithness flags.

The Lower or Perth-Forfar Old Red is characterized by the presence of *Psilophyton princeps*, Dawson, and var. *ornatum*, Dawson, *Psilophyton robustius*, Dawson, *Arthrostigma gracilis*, Dawson, *Zosterophyllum Myrtonianum*, Penhallow, and *Parka decipiens*, Fleming, etc.

As far as I know at present, each of these divisions is characterized by a flora peculiar to itself, but the whole subject requires a thorough revision in the light of more recent discoveries.

R. KIDSTON.

## PART II.

### List of Publications Referring to the Geology and Mineralogy of the District included in Sheet 85.

1775. History of the Province of Moray. Shaw.

1830. "An account of the Great Floods of August 1829 in the Province of Moray and the adjoining districts," by Sir Thos. Dick Lauder, Bt.

1835. "Essay on the Geology of Moray," by John Martin. *Highland Soc. Trans.*, Vol. V., new series.

1836. "On the Geology of Moray," same author. *Quart. Journ. Agriculture*, No. XXXV.

1840. Geological Map of Scotland. John Macculloch, F.R.S.

1842. "Sketch of the Geology of Moray," by Patrick Duff.

1842. "The Geognosy of Banffshire," by R. F. H. Cunningham. *Trans. Highland Soc.*, Vol. XIV.

1842. "On the Relations of the different parts of the Old Red Sandstone in which Organic Remains have recently been Discovered in the Counties of Murray, Nairn, Banff and Inverness," by J. G. Malcomson, M.D. *Proc. Geol. Soc.*, Vol. III.

1858. "On the Sandstones of Morayshire and Elgin containing Reptilian Remains, and on their Relations to the Old Red Sandstone of that County," by Sir R. I. Murchison. *Quart. Journ. Geol. Soc.*, Vol. XV., p. 419.

1859. "The Geology of the Lower or Northern part of the Province of Moray," by Dr. Gordon of Birnie. *Edin. New Phil. Journ.*, Vol. IV.

1860. "Notes on Fossiliferous Localities of the Old Red Sandstone of the East of Scotland," Gregory. *The Geologist*, Vol. III., pp. 142-148.

1866. "Geology of the North of Scotland," by Prof. Nicol.

1871. "On the Older Metamorphic Rocks and Granite of Banffshire," by T. F. Jamieson, F.G.S. *Quart. Journ. Geol. Soc.*, Vol. XXVII., p. 101.

1877. Same title and author. *Geol. Mag.*, Vol. VIII., p. 134.

1871. "On the Old River Terraces of the Spey" by Rev. Thos. Brown. *Proc. Roy. Soc. Edin.*, Vol. VII., p. 399.

1872-3. "Reports of the Committee on Boulders appointed by the Royal Society of Edinburgh," D. Milne Home. *Proc. Roy. Soc. Edin.*, Vols. VII., VIII.

1874. "On the Last Stage of the Glacial Period in North Britain," by T. F. Jamieson. *Quart. Journ. Geol. Soc.*, Vol. XXX.

1878. "On the Transportation of Rocks found on the S. Shore of the Moray Firth," by W. Jolly. Communicated to the Report of Boulder Committee. *Proc. Roy. Soc. Edin.*, Vol. X., p. 178.

1878. "The Old Red Sandstone of Western Europe," by Sir Arch. Geikie, F.R.S. *Trans. Roy. Soc. Edin.*, Vol. XXVIII., p. 345.

1879-83. "Chapters on the Mineralogy of Scotland," Prof. M. F. Heddle. *Trans. Roy. Soc. Edin.*, Vols. XXVIII.-XXX. (Contains several references to mineral localities within the Sheet.)

1882-84. "Reports of the Boulder Committe of the Royal Society." *Proc. Roy. Soc. Edin.*, Vols. XI., XII.

1894. "Annual Report of the Geological Survey for the year 1893," p. 264.

1896. "The Sands and Sandstones of Eastern Moray," by Wm. Mackie, M.D. *Trans. Edin. Geol. Soc.*, Vol. VII.

1896. "The Extinct Vertebrate Animals of the Moray Firth Area," by R. H. Traquair, M.D., F.R.S. *Fauna of the Moray Basin*, *Harvie-Brown* and *Buckley*, Vol. II.

1897. "Additional Notes on the Fossil Fishes of the Upper Old Red Sandstone of the Moray Firth Area," R. H. Traquair, M.D., F.R.S. *Proc. Roy. Phys. Soc. Edin.*, Vol. XIII.

1899. "Seventy Chemical Analyses of Rocks, (chiefly from the Moray Area) with Deductions," by W. Mackie, M.D. *Trans. Edin. Geol. Soc.*, Vol. VIII.

1900. "On Differences in Chemical Composition between the Central and Marginal Zones of Granite Veins, with further evidence of exchanges between such Veins and the Contact Rocks," by the same author. *Trans. Edin. Geol. Soc.*, Vol. VIII.

1900. "Notes on the Distribution of Erratics over Eastern Moray," by the same author. *Trans. Edin. Geol. Soc.*, Vol. VIII.

1901. "The River Spey," by Lionel W. Hinxman. *Scottish Geographical Magazine*, April, 1901.

1901. "The Interstitial or Cementing Substances in the Elgin Sandstones," by W. Mackie. M.D. *Trans. Northern Assoc. of Scientific Societies.*

## PART III.

### List of Microscopic Sections Prepared from Rocks Collected in Sheet 85.

*The Newer Granites and Diorites.*

| No. | Name. | Locality. | |
|---|---|---|---|
| 9568. | Biotite Granite. | Glack Harness, between Round Hill and Meikle Conval. | See p. 36. |
| 5248. | Do. | Carron, Strathspey. | See p. 37. |
| 9554. | Do. | Ruthrie, Aberlour. | See p. 36. |
| 9567. | Do. | Burn of Rothes, below Netherly. | See p. 38. |
| 9598. | Muscovite Granite. | Nether Cluny, 2 miles S.S.W. of Dufftown. | See p. 37. |
| 9552. | Quartz Diorite. | ¼ mile S. of Dandaleith. | See pp. 37, 38. |
| 9551. | Do. | Do. do. | See pp. 37, 38. |
| 9553. | Do. | Do. do. | See pp. 37, 38. |
| 9608. | Do. | Hill above Cone Rock, Rothes. | See p. 33. |
| 9607. | Do. | E. of Stob Hill. | See pp. 33, 39. |
| 9550. | Do. | Netherly, Burn of Rothes. | See pp. 38-41. |
| 1632. | Do. | Do. do. | See pp. 38-41. |
| 1633. | Do. | Do. do. | See pp. 38-41. |
| 1634. | Do. | Do. do. | See pp. 38-41. |
| 9606. | Biotite Granite. | Railway cutting, E. of tunnel Craigellachie. | See p. 39. |
| 9605. | Diorite, with inclusions of schist. | Milltown of Ruthrie, Aberlour. | See p. 37. |
| 7769. | Camptonite. | E. bank of Spey, Hollybush Pool, Aikenway. | See p. 41. |

*The Foliated Igneous Masses.*

| No. | Name. | Locality. | |
|---|---|---|---|
| 1758. | Augen Gneiss. | Keith, Banffshire. | See p. 44. |
| 9548. | Hornblende Schist. | Kingshaugh, Blackwater. | See p. 46. |
| 9600. | Serpentine. | Blackwater, 2 miles above Ardwell Bridge | See p. 45. |
| 9601. | Epidiorite. | Do. Do. | See p. 44. |
| 2963. | Flaser Gabbro. | Blackwater, 1 mile N. of Lodge. | See pp. 30, 44. |
| 2964. | Do. | Do. Do. | See p. 45. |
| 9549. | Calc Hornblende Schist. | 300 yards above bridge over Blackwater, Ardwell. | See p. 46. |
| 9565. | Hornblende Schist. | Burn at Findouran, Burn Treble. | See p. 29. |
| 1783. | Hornblende Rock. | Shenwell, Blackwater. | See p. 45. |
| 9563. | Diallage Peridotite. | Craigdorney, River Deveron. | See p. 45. |

*Metamorphic Schists* (*Moine Schists*).

| No. | Name. | Locality. | |
|---|---|---|---|
| 2077. | Biotite Gneiss. | Craigellachie cutting. | See p. 32. |
| 2078. | Do. | Do. do. | See p. 32. |
| 5249. | Muscovite Biotite Gneiss. | Blue Hill, Aberlour. | See p. 32. |
| 5250. | Biotite Gneiss and Biotite Granite. | Slack of Ballanteem, Aberlour. | See p. |
| 1635. | Garnet Muscovite Gneiss. | Rothes Burn. | See p. 28. |
| 9556. | Quartzite. | Hunt Hill. | See p. 31. |
| 9560. | Quartz Felspar Hornfels. | Netherly, Burn of Rothes. | See p. 51. |
| 9558. | Biotite Hornfels. | Do. do. | See p. 51. |
| 9561. | Do. | Do. do. | See p. 51. |
| 9559. | Cordierite Hornfels. | Do. do. | See p. 52. |
| 9609. | Andalusite Hornfels. | Do. do. | See p. 53. |
| 9610. | Quartzite. | North end of Craigellachie Bridge. | See p. 51. |
| 5251. | Biotite Granite and Biotite Schist. | Ballanteem, Aberlour. | See p. 51. |

*Banffshire Series.*

| No. | Name. | Locality. | |
|---|---|---|---|
| 9556. | Grit. | Allt Deach, Ardwell. | See p. 23. |
| 1759. | Micaceous Grit. | Drummuir, S. of Keith. | See p. 48. |
| 981. | Schistose Grit. | Railway cutting, Mulben. | See p. 48. |
| 933. | Phyllite. | Do. do. | See pp.21,48. |
| 934. | Do. | Do. do. | See pp.21,48. |
| 935. | Do. | Do. do. | See pp.21,48. |
| 935*a*. | Do. | Do. do. | See pp.21,48. |
| 935*b*. | Do. | Do. do. | See pp.21,48. |
| 1761. | Quartzite, with agate veins. | Cone Hill, Rothes. | See p. 13. |
| 2074. | Mica Schist. | Haugh's Quarry, Keith. | See p. 22. |
| 1765. | Limestone. | Blackhillock Quarry, Keith. | See pp.18,48. |
| 1768. | Micaceous Limestone. | Do. do. | See pp.18,48. |
| 1766. | Do. do. | Do. do. | See pp.18,48. |
| 1767. | Do. do. | Do. do. | See pp.18,48. |
| 2091. | Black Schist with Tremolite. | Boharm. | See pp.19,50. |
| 9594. | Do. do. Actinolite. | Belnagarrow, 2½ miles N.E. of Craigellachie. | See pp.19,50. |
| 9597. | Black Schist. | 1 mile N.W. of Edington Ho., 2½ miles S. of Keith. | See p. 20. |
| 9596. | Do. | Stream between Blackhillock and Tulloch, 2 miles N. of Dufftown. | See p. 19. |
| 9564. | Calc-silicate Hornfels. | Near Tullochallum, Dufftown. | See pp.50,56. |
| 9604. | Do. do. | Railway cutting E. of Dufftown. | See pp.50,56. |
| 9603. | Chiastolite Slate. | Ardwell Inn, Blackwater. | See pp.53-54. |
| 9603. | Biotite Hornfels. | Above Blackwater Bridge, Ardwell. | See p. 56. |
| 9599 and 9599*b*. | Andalusite and Staurolite Schist. | Blackwater, 2 miles above Ardwell Bridge. | See p. 54. |
| 9595. | Calcareous Grit. | Little Newton, 2 miles N.E. of Craigellachie. | See p. 50. |

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